Appendix L

Equipment Brochures

AUGER MONSTER®

www.jwce.com

Overview

The Auger Monster® is a robust and affordable wastewater screen which combines three of JWCs finest technologies – a grinder, a fine screen and a compactor. It removes trash and unwanted solids, so the treatment plant runs more efficiently and life is easier for operators and managers.

First, a powerful Muffin Monster® or Channel Monster® grinder shreds clumps of rags, clothing and debris. Next, solids are captured by a perforated screening trough and removed by a rotating auger. As solids are removed, dual wash water zones clean off fecal material. The auger then conveys solids to the discharge point where the integrated compactor (optional) squeezes out water before depositing the cleaned and dried material into a dumpster.

The cleaner, more compact discharge keeps odors to a minimum and lowers disposal costs, as less water and fecal material are sent to the landfill.

With the Auger Monster, wastewater screening couldn't get any easier—it's the only one that's all-in-one!

Cleaner, More Compact Discharge

Auger Monster discharge is cleaner, drier and more compact. The Auger Monster has become a favorite among wastewater operators and managers since it makes the headworks area cleaner, less time consuming and less expensive to operate.

MUFFIN MONSTER®
A JWC Environmental Brand

Features & Benefits

Dual-Shafted Grinder

- Proven Muffin Monster grinding technology.
- Shreds long, stringy material to prevent wrapping on auger.
- Breaks-up clumps for more efficient washing.

Spiral Lifting Auger

- Solids are removed while soft organics are washed back into the channel through a perforated screen.
- Various perf sizes: 5/64”, 1/8” or 1/4” (2, 3 or 6 mm).

Cleaner Screenings Discharge

- Integrated spray wash launders screenings and removes fecal material for cleaner discharge and reduced odors.

Modular Headworks System

- Integrates high-flow grinding, screening, washing and de-watering technology.
- Placement in existing channel with little or no civil work.
- Easy installation in outdoor locations.

Easy Access, Pivoted Auger

- The auger is mounted to a tilt and swivel point for easy removal and servicing.
- Operators can easily bring the screening trough, auger brush and auger conveyor to deck level for inspection.

Automated PLC Monitoring and Controls

- Auto load sensing and reversing protects the system.
- Adjustable, differential run times for optimal solids removal and operating life.
- Auger “fail-safe” mode ensures system continues running even if electronics are disabled.

Materials of Construction

Channel Frame: Stainless steel
Cutters and Spacers: Hardened alloy steel
Shafts: Heat treated hexagonal steel
End Housings and Covers: Ductile Iron
Seal Faces: Tungsten carbide
Auger Spiral: Alloy steel

Flow from grinder to auger

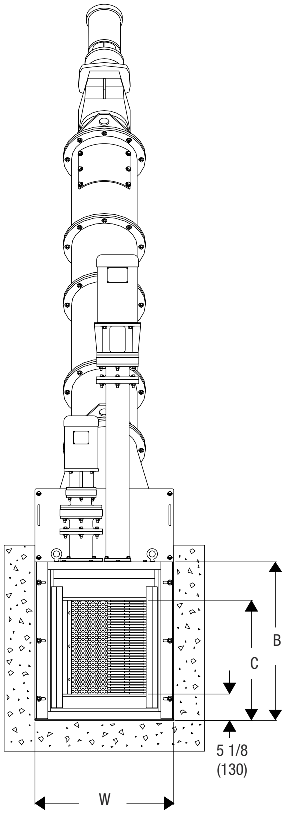
Replaceable auger brush keeps perforated screen clean and helps transport solids.

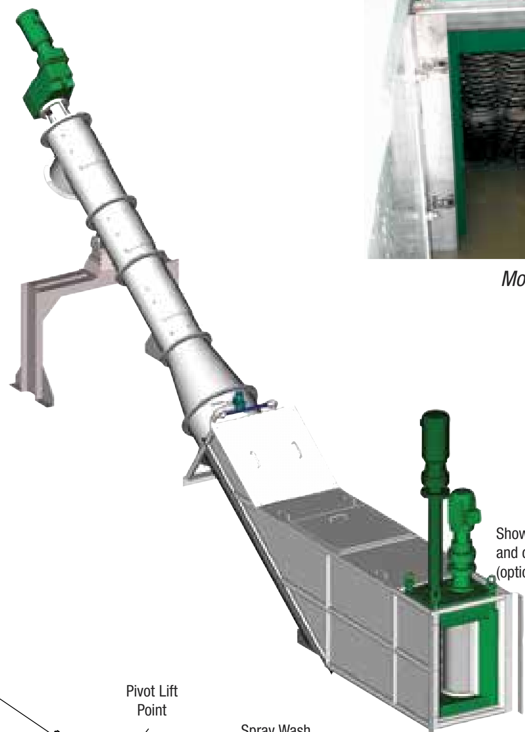
Auger Monster®

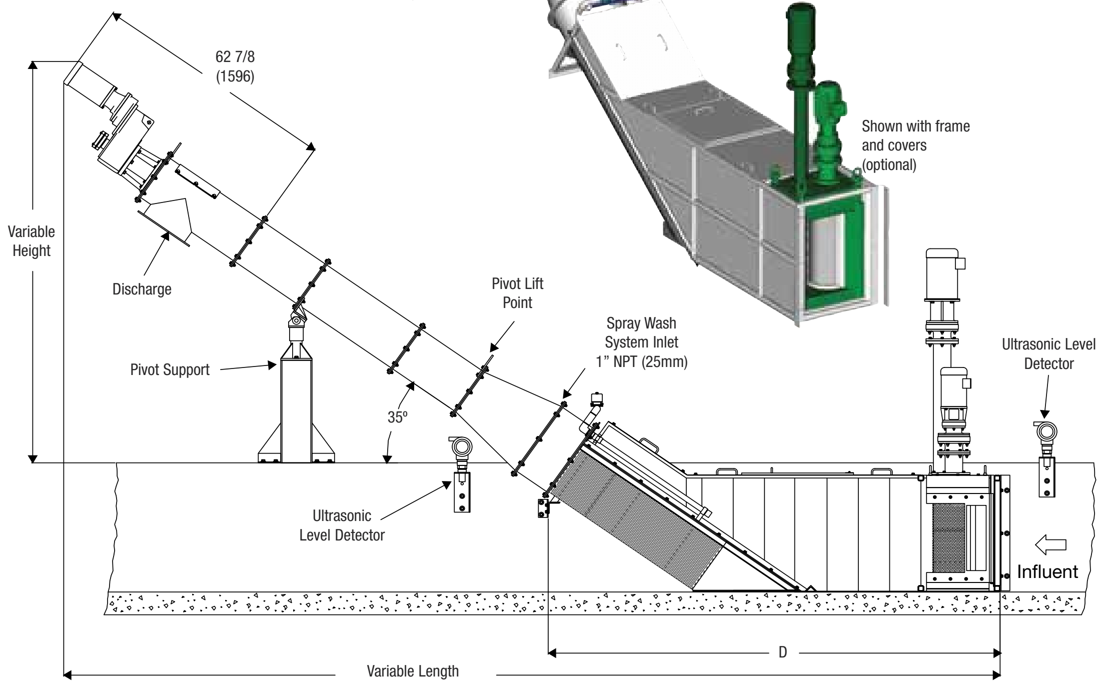
Model ACE

ACE - Channel Monster & Screen

5 HP (3.7 kW) grinder motor 1 HP (.75 kW) drum motor. Immersible and other electric motors are optional.
2 HP (1.5 kW) TEFC auger motor. Channel depth from 26" (660 mm) and up - based on frame height. Flow based on optimum channel conditions and 1/4" (6 mm) perforated screen.







Model	B inches (mm)	C inches (mm)	D inches (mm)	W - Min. Channel Width* w/o frame inches (mm)	W - Min. Channel Width* w/ frame inches (mm)	Flow Capacity MGD (m³/hr)
ACE1810-480	30-11/16 (779)	23-5/16 (592)	110-9/16 (2808)	24 (610)	30 (762)	2.2 (342)
ACE2410-480	36-5/16 (922)	29-1/16 (738)	125-1/16(3177)	24 (610)	30 (762)	2.9 (465)
ACE3210-480	44-3/16 (1122)	36-15/16 (938)	139-5/8 (3546)	24 (610)	30 (762)	4.0 (636)
ACE4010-480	52-1/16 (1322)	44-11/16 (1135)	154-1/8 (3915)	24 (610)	30 (762)	5.1 (807)
ACE5010-480	62-1/16 (1576)	54-11/16 (1389)	168-11/16 (4285)	24 (610)	30 (762)	6.5 (1029)
ACE6010-480	72-7/16 (1840)	65-1/16 (1653)	183 (4648)	24 (610)	30 (762)	8.0 (1261)

** Please consult factory for final applications assistance.*

Auger Monsters discharging into a horizontal conveyor

Two auger conveyors converge

Auger Monsters and cross conveyor

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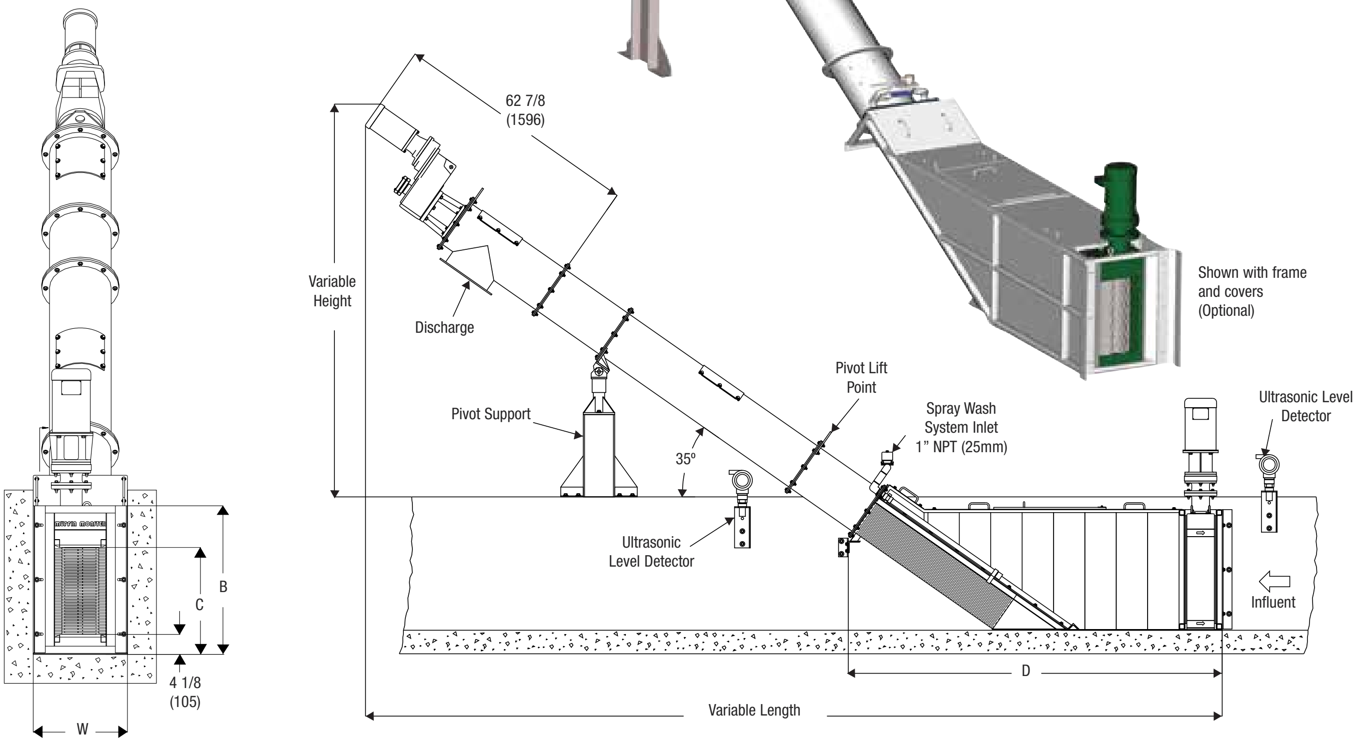
Auger Monster®

Model AGE

AGE - Muffin Monster & Screen

5 HP (3.7 kW) grinder motor. Immersible and other electric type motors are optional. 2 HP (1.5 kW) TEFC auger motor. Channel depth from 26” (660 mm) and up - based on frame height. 285 mm unit shown. 170 mm and 480 mm options also available. Flow based on optimum channel conditions and 1/4” (6 mm) perforated screen.



Model	B inches (mm)	C inches (mm)	D inches (mm)	W - Min. Channel Width w/o frame inches (mm)	W - Min. Channel Width* w/ frame inches (mm)	Max Flow MGD (m³/hr)
AGE1800-170	29-1/2 (749)	21-7/8 (556)	85 (2159)	12 (305)	16 (406)	1 (146)
AGE2400-170	35-1/4 (895)	27-7/8 (708)	99-3/4 (2530)	12 (305)	16 (406)	1.2 (194)
AGE3200-170	43 (1092)	35-7/8 (911)	114-1/8 (2899)	12 (305)	16 (406)	1.6 (258)
AGE4000-170	51 (1295)	43-7/8 (1114)	128-11/16 (3269)	12 (305)	16 (406)	2.1 (331)
AGE5000-170	61 (1549)	53-7/8 (1368)	143-3/16 (3638)	12 (305)	16 (406)	2.8 (435)
AGE6000-170	71-3/8 (1813)	63-7/8 (1622)	157-7/16 (3999)	12 (305)	16 (406)	3.5 (552)
AGE1800-285	29-1/2 (749)	21-7/8 (556)	94-5/8 (2402)	16 (406)	22 (559)	1.1 (168)
AGE2400-285	35-1/4 (895)	27-7/8 (708)	108-3/4 (2762)	16 (406)	22 (559)	1.4 (223)
AGE3200-285	43 (1092)	35-7/8 (911)	123-5/8 (3139)	16 (406)	22 (559)	1.9 (298)
AGE4000-285	51 (1295)	43-7/8 (1114)	137-13/16 (3499)	16 (406)	22 (559)	2.4 (382)
AGE5000-285	61 (1549)	53-7/8 (1368)	151-11/16 (3853)	16 (406)	22 (559)	3.2 (505)
AGE6000-285	71-3/8 (1813)	63-7/8 (1622)	165-1/2 (4203)	16 (406)	22 (559)	4.1 (642)
AGE1800-480†	28-1/2 (724)	22-15/16 (583)	107-1/8 (2721)	24 (610)	30 (762)	1.3 (200)
AGE2400-480†	35-1/2 (901)	30 (762)	121-7/8 (3096)	24 (610)	30 (762)	1.7 (274)
AGE3200-480†	43 (1092)	37-1/2 (952)	136-1/4 (3461)	24 (610)	30 (762)	2.3 (359)

**Please consult factory for final applications assistance.*
†Available only with 40K Muffin Monster model 0018, 0024 or 0032

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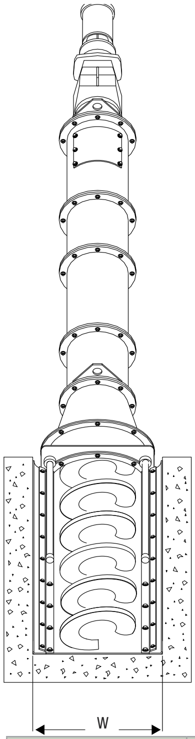
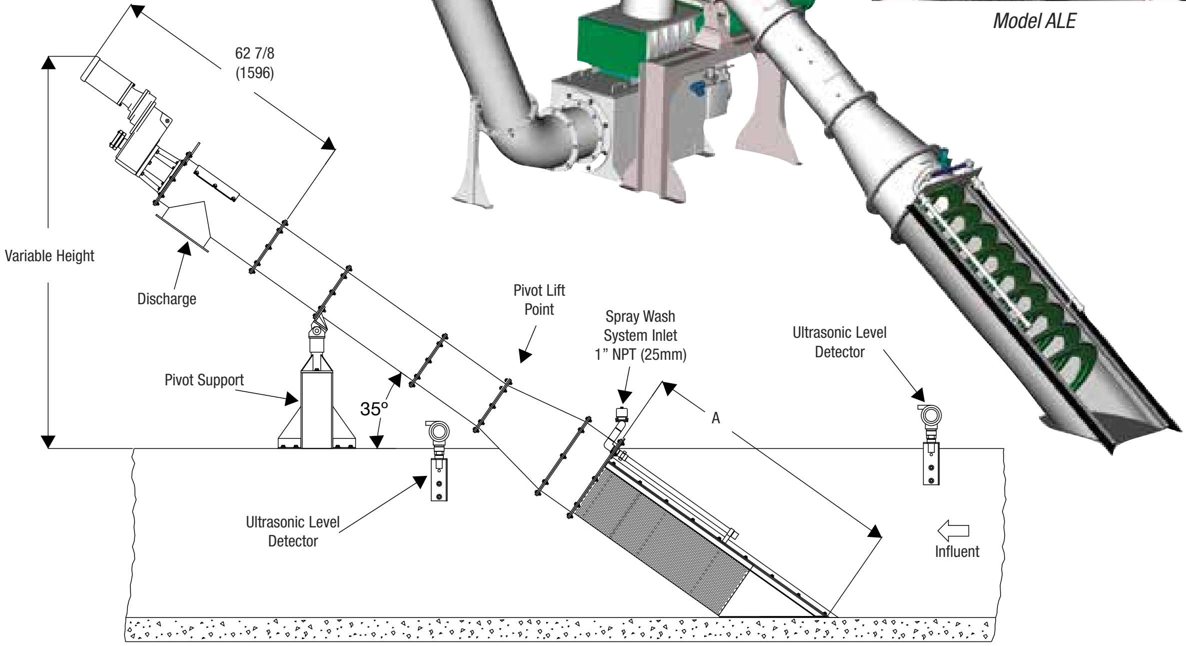
Auger Monster®

ALE - Auger / No Grinder

2 HP (1.5 kW) TEFC auger motor. Immersible and other electric motors are optional. Channel depth from 26” (660 mm) and up - based on frame height. 285 mm shown with optional Screenings Washer Monster®. 170 mm and 480 mm options also available.

Model ALE





Model	A inches (mm)	W - Min. Channel Width* - inches (mm)	Flow Capacity MGD† (m³/hr)
ALE1800-170	53-11/16 (1364)	12 (305)	1.6 (265)
ALE2400-170	68-5/16 (1735)	12 (305)	2.2 (345)
ALE3200-170	82-13/16 (2103)	12 (305)	2.9 (456)
ALE4000-170	97-7/16 (2475)	12 (305)	3.6 (566)
ALE5000-170	111-15/16 (2843)	12 (305)	4.5 (707)
ALE6000-170	123-1/4 (3207)	12 (305)	5.4 (854)
ALE1800-285	58-15/16 (1497)	16 (406)	2.1 (339)
ALE2400-285	73-1/2 (1867)	16 (406)	2.8 (440)
ALE3200-285	88-1/4 (2242)	16 (406)	3.6 (579)
ALE4000-285	102-13/16 (2611)	16 (406)	4.5 (716)
ALE5000-285	117-3/8 (2981)	16 (406)	5.6 (893)
ALE6000-285	131-3/4 (3346)	16 (406)	6.8 (1078)
ALE1800-480	66-1/4 (1683)	24 (610)	3.4 (542)
ALE2400-480	80-13/16 (2053)	24 (610)	4.4 (694)
ALE3200-480	95-3/8 (2423)	24 (610)	5.7 (902)
ALE4000-480	109-15/16 (2792)	24 (610)	7.0 (1107)
ALE5000-480	124-1/2 (3162)	24 (610)	8.7 (1370)
ALE6000-480	138-13/16 (3526)	24 (610)	10.4 (1646)

** Please consult factory for final applications assistance.*
† Based on 1/4” (6 mm) perforated screen

Solids captured and removed by auger

Discharge into optional bagger

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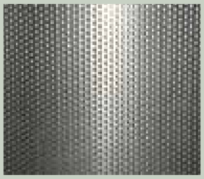
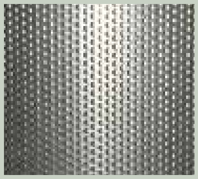
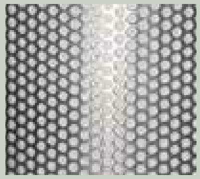
Auger Monster®

Screen Sizes

- 5/64”, 1/8” or 1/4” (2, 3 or 6 mm) perforated screens.


2 mm


3 mm


6 mm

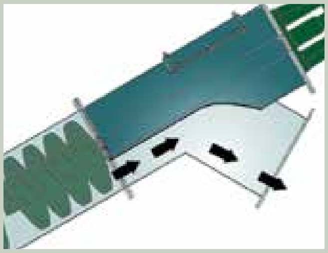
Conveyor Options

- Convey discharged solids vertically, horizontally or at an angle.
- Sluice conveyor

Patented Compaction Zone

- Compactor at the end of the auger compresses material to save on transport and disposal fees.

Conveyor


JWCE patented compaction zone

Dual-Shafted Grinder

- Various cutter stack heights to fit your channel and flow requirements.
- Multiple cutter options.
- High-flow side rails.
- Channel Monster® with high-flow screening drum.
- 40K Series for prison sites or high solids loading.


30K Grinder Option


40K Grinder Option


Channel Monster Option


Electric motor


JWC exclusive: high-efficiency immersible motor


Touch Screen Controller

Motors

- Single or Multi-drive
- Electric motor: 5, 10 HP (3.7, 7.5 kW)
- Explosion proof electric motor: 5, 10 HP (3.7, 7.5 kW)
- Exclusive Immersible Motor: 5, 10 HP (3.7, 7.5 kW)

Extended Motor Shaft

- Drive shaft extension puts motor above the highest overflow level. Available in 6” (152 mm) increments.


Extended shaft

Overflow Bar Screens

- Stainless steel bars attached to frame inhibit solids from passing during an overflow event.

High-tech Controllers

- Enclosure options: NEMA 4x 304 stainless steel; NEMA 4x 316 stainless; NEMA 7 explosion-proof.
- Auger ‘fail-safe’ mode ensures system continues running.


Bagger

Discharge Bagger

- Screenings can be collected inside a plastic bag affixed to the end of the discharge chute.
- Operator simply pulls the trash bag from the ring and ties it off.


Blanket

Cold Weather System

- Heat tracing and insulation blanket inhibit freezing.
- High performance is assured in colder climates.
- Operates outdoors, cover recommended but not required.

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Since its founding in 1973, JWC Environmental has become a world leader in solids reduction and removal systems. For municipal wastewater collections, headworks and bio-solids operations we offer our legendary Muffin Monster grinders and Monster Separation Screening systems to solve unique processing situations.

JWC Environmental also supports commercial and industrial applications with our Monster Industrial, IPEC and FRC products. We are ready to take on challenging size reduction problems in industrial processes as well as help customers run efficient and compliant industrial wastewater treatment operations.

JWC Environmental is headquartered in Santa Ana, California, and has a global network of representatives, distributors and regional service centers to provide customer support. For more information, visit us at www.jwce.com.

JWC Environmental®
Trust Monster Quality™

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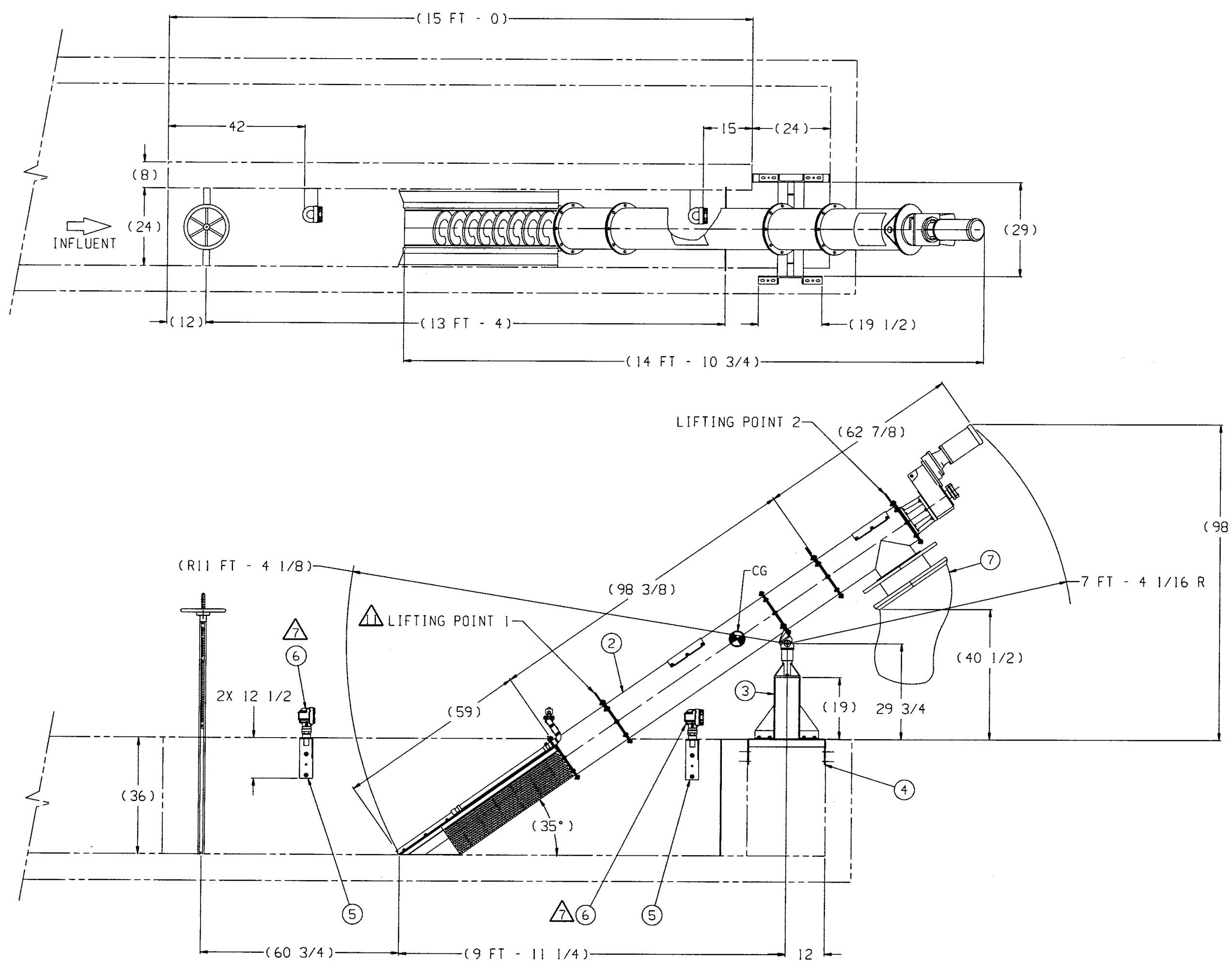
(AugerMonster-NA-JWCE-0317)

DRAWING NO. ALE1800-107033



JWC ENVIRONMENTAL
2600 South Garnsey, Santa Ana, California 92707

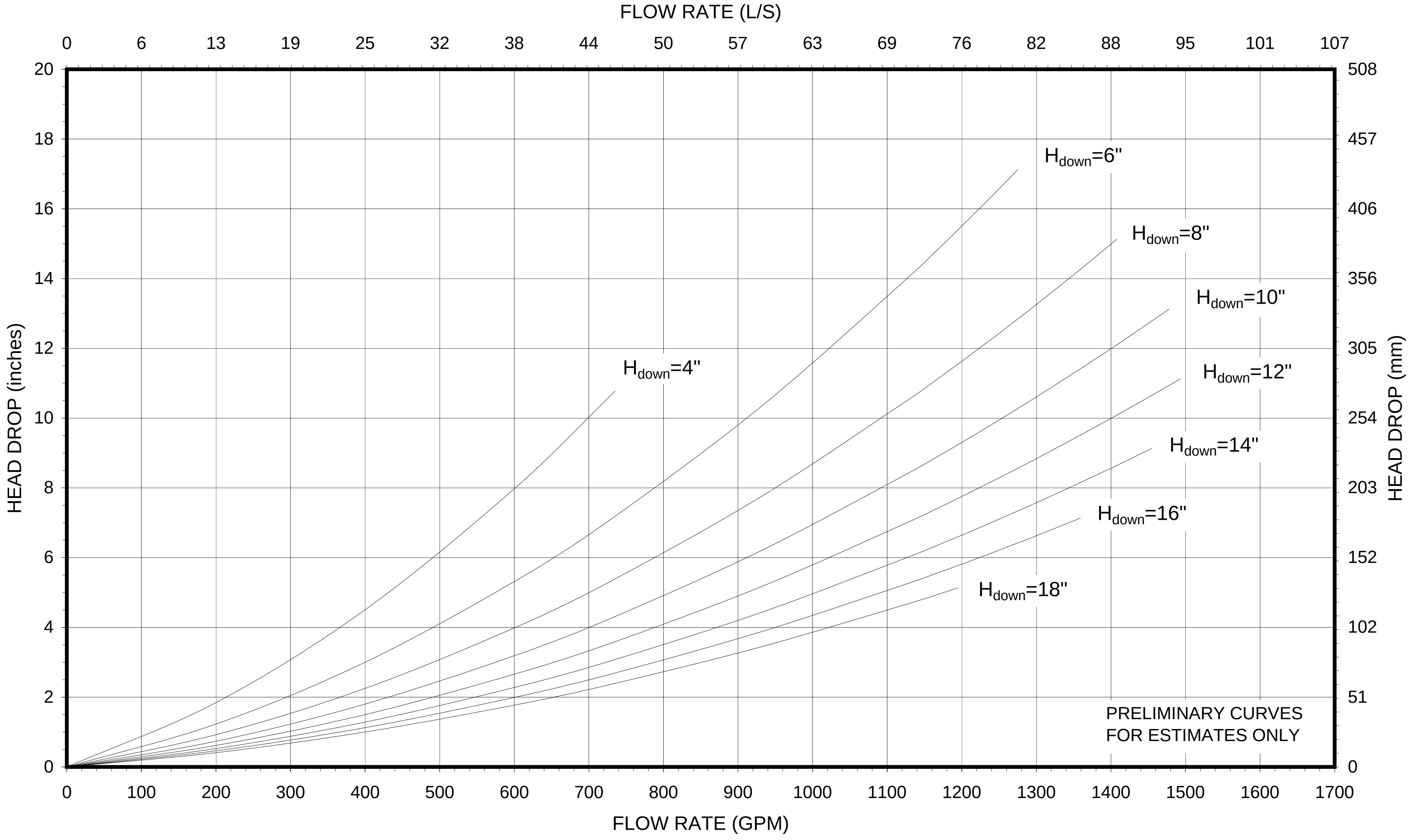
AUGER MONSTER GENERAL ARRANGEMENT
MODEL ALE1800-285
BRANDENBURG, KY

SIZE	CODE IDENT NO.	DRAWING NO.	REVISION
D	53242	ALE1800-107033	A

SCALE 1/16 SHEET 2 OF 2

HEAD DROP
AUGER MONSTER
MODEL ALE1800-285-XE

3-20-07



PROPOSAL ON ENHANCING LAGOON WASTEWATER TREATMENT USING ADVANCED TECHNOLOGIES

Proposal Submitted to:

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August 2017 v2

INTRODUCTION

GRW's client has a two identical lagoons, located in Bradenburg, KY, operating in series, and the following design and operating conditions were provided:

Design and Operating Parameter	**Value**
Length/Width	225 ft each
Depth	17.5 ft
Flowrate	232,000 gpd Average 312,000 gpd Design 932,000 Maximum
Influent Water Parameters	
BOD (5 days)	401 mg/L 334 mg/L Design
TSS	371 mg/L 323 mg/L Design
Ammonia-N	27 mg/L Design
Effluent Water Parameters	
BOD (5 days)	16 mg/L
TKN (NH3-N)	10.87 mg/N
TSS	32 mg/L
Discharge Limits	
BOD (5 days)	30 mg/L (monthly average)
TKN	20 mg/L (monthly average)
TSS	30 mg/L (monthly average)
Other Information	
Four aerators (15 HP each) in each lagoon (replaced in Jan 2014) Duckweeds growing in the lagoon Sludge depth 6 ft and 4 ft Ammonia-Nitrogen violations in winter time	

During the winter months, the following data on Ammonia-Nitrogen was collected for the effluent:

Year	**Average Ammonia-N concentration (mg/L)**					
	Jan	**Feb**	**March**	**April**	**May**	**June**
2014	24	30	35	32	33	27
2015	29	32	24	22		
2016	22	20				

Duckweed is a small, leafy flowering plant that proliferates rapidly in stagnant or slow-moving water, and it indicates the presence of nutrients in the water. It reduces oxygen transfer into the lagoon, thereby decreasing dissolved oxygen levels and reducing BOD treatment capacity of the lagoon. Duckweed is very effective at uptaking carbon, nitrogen, phosphorus, pathogens, and toxins, acting as a natural water filter, except it does not metabolize the nutrients. Instead when it dies, it settles down and decays and releases the nutrients back into the water. Also, decay of duckweeds consumes oxygen and generates BOD in the water. Lack of dissolved oxygen in the lagoon can result in generation of odors, and release of ammonia-N from the accumulated sludge layer at the bottom.

PROPOSED MODIFICATIONS

Based on detailed simulations that were run at both the average and maximum flowrates, and using the data provided, it was clear that there was inadequate dissolved oxygen in the first lagoon, which was allowing ammonia-nitrogen to enter the polishing (second lagoon), resulting in growth of duckweed. The four aerators, in the first lagoon were unable to provide the dissolved oxygen needed to achieve oxidation of ammonia-nitrogen to nitrates, as well as aerobically decompose the sludge produced by aerobic oxidation of the influent BOD. This has resulted in the accumulation of sludge layer at the bottom of the lagoon.

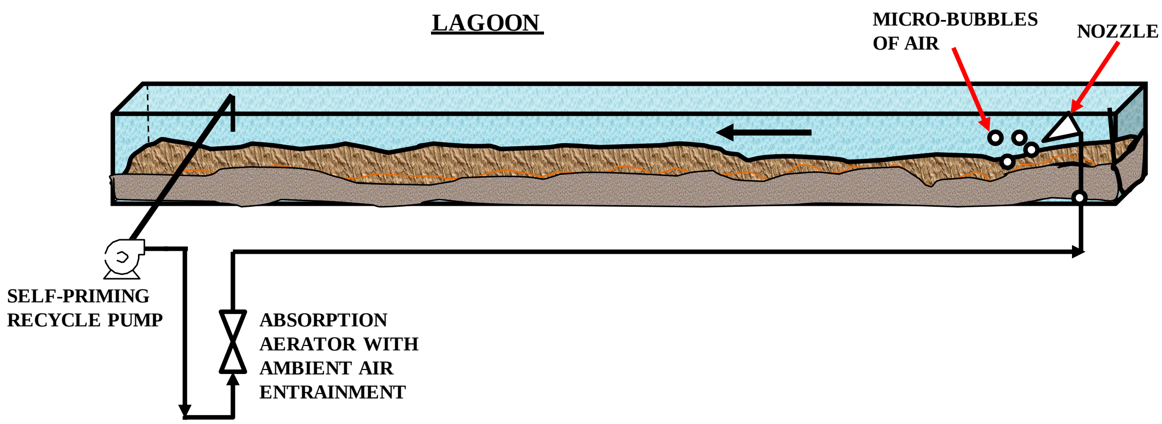
Sludge depth within the lagoon also results in reducing hydraulic retention time, and even though this sludge depth is not uniform throughout the lagoon, it is substantial enough to result in major operational issues:

1. Major reductions in hydraulic retention time and hence reduced treatment capacity;

2. Anoxic decomposition of the sludge layer results in generation of BOD and ammonia-nitrogen, which increases the need for additional dissolved oxygen; and

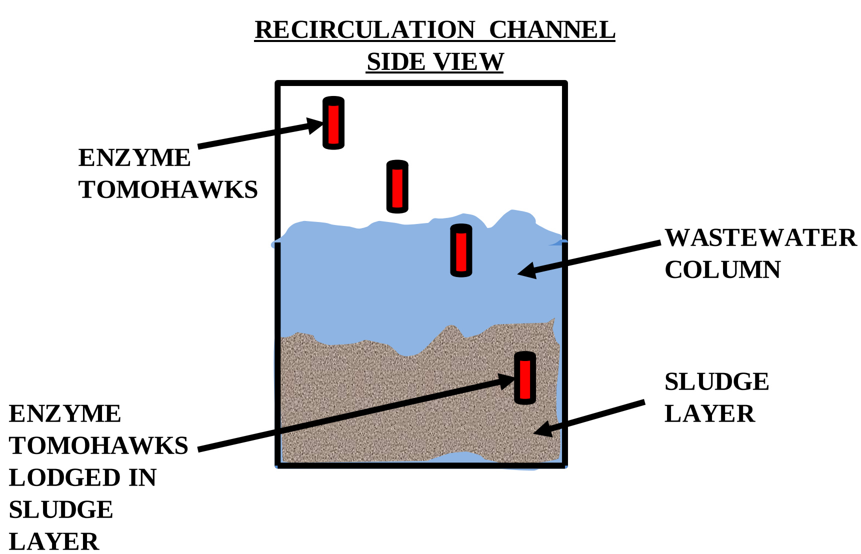
3. Incurs dredging costs, which are substantial and will cause large amounts of waste sludge to be dewatered and land filled.

To accelerate the degradation of the sludge blanket layer, a **micro-bubble aeration** system is recommended to provide additional dissolved oxygen not only at the upper surface of the water, but below the water level at the bottom, where the sludge blanket layer exists. In addition, it is proposed to add enzymes with this injection of air-water, to accelerate the biodegradation of the sludge blanket layer. The design of this microbubble aeration consists of an external self-priming pump, which takes treated effluent from the lagoon, and pumps it back through nozzles with air, that is drawn in using a specially designed venturi system (Absorption Aerator), as shown below:



The injection of the air-water mixture into the lagoon water, creates a highly oxygenated zone of water, wherein dissolved oxygen exists throughout the depth of the lagoon, including in the sludge blanket layer. This allows the sludge blanket layer to biodegrade rapidly, and over a 6 month – 1 year period, all of the sludge blanket layer will be biodegraded. This will increase the capacity of the lagoon substantially, and other benefits will also be derived, as pointed out earlier.

Note that there is no injection of enzyme solution in the recycle flow line. To ensure a steady-breakdown of the sludge layer at the bottom of the lagoon, it is proposed to use **Enzyme-Tomahawks**, which are solid spikes, which when dropped above the water surface, sink to the bottom and lodge themselves into the sludge layer at the bottom of the lagoon, as shown below in the figure.



Enzyme-Tomahawks are composed of enzymes, billions of microorganisms and micro-nutrients to accelerate the biodegradation of the sludge layer. Typically, they are supplied as

Enzyme solution, which is injected into the recycle flow. However, any liquid enzyme solution added, will washout with the water flow before it has spent enough time to breakdown the sludge layer at the bottom. Hence, in order to provide enough retention time of the enzyme mixture with the sludge layer, the mixture of enzymes, microorganisms and micro-nutrients will be supplied as solid Enzyme-Tomahawks, that will bury themselves into the sludge layer, when added from the top of the water layer, and release the enzymes, microorganisms and micro-nutrients within the sludge layer, while the nozzles in the water column will inject micro-bubbles of air and water into the water column. These micro-bubbles will provide much-needed dissolved oxygen and in conjunction with the enzyme release, within the sludge layer by the Enzyme-Tomahawks, the sludge layer will begin to biodegrade aerobically.

In addition, the use of **Waving Biomedia**, will also assist in improving the performance of the lagoon. Waving Biomedia consists of high surface area foam, which is specially coated to enhance the formation of active biofilms within the foam structure. This column of high surface area foam, is weighted down, so that it does not have to be installed with any hardware, but simply stays in place due to the weight at the bottom. The use of Waving Biomedia allows additional biomass growth to occur on the foam structure in the form of biofilms, which increases the concentration of biomass in the water from 1,500 – 2,000 mg/L of suspended biomass concentration to an overall concentration of 14,000 – 16,000 mg/L – this is a 600 – 800% increase in biomass concentration within the lagoon water, which increases the capacity of the lagoon substantially.

In addition, the use of Waving Biomedia provides the following benefits:

1. Waving Biomedia provides simultaneous nitrification and denitrification capability, which exists minimally with suspended cultures; the outside surface of the Waving Biomedia is aerobic, and allows nitrifiers to immobilize within the active biofilms, which nitrifies the ammonia, while the denitrifiers, which are slow growing organisms, exist within the foam structure, where is low oxygen levels; hence the inner area of the Waving Biomedia allows denitrification to occur, converting the nitrates to nitrogen gas;

2. The use of Waving Biomedia prevents the washout of active nitrifiers and denitrifiers from the lagoon water, especially in the wintertime, when currently there are ammonia-nitrogen violations in the effluent;

3. Waving Biomedia increases the active concentration of biomass 600 – 800%, which improves the performance of the lagoon, thereby allowing the effluent water to meet the discharge limits; the Waving Biomedia is just added to the lagoon, it does not have to be installed with hardware and can be easily lifted out of the lagoon, if the lagoon has to be dredged.

Additional information on the Waving Biomedia, Microbubble aeration and Enzyme Tomahawks are attached in the Appendix section of this proposal.

BUDGETARY COSTS

Based on the data provided and the desired BOD discharge limit of 30 mg/L, it is expected that 72 lbs of additional oxygen needs to be transferred into the lagoon water per hour, which will need a water flowrate of 1,100 gpm through the Absorption Aerator system. As described earlier, the specially designed venturi system draws in ambient air and creates microbubbles when injected into the lagoon water. These microbubbles will create "white water" which is a dispersion of very small air bubbles, less than 50 microns in diameter, which will remain in the water for a very long time, instead of just rising through the water.

Waving Biomedia will also be used within the existing lagoon, in areas where the dissolved oxygen is higher due to microbubble aeration. Each piece of Waving Biomedia, which will be 17.5 ft long (depth of water), will be placed near the microbubble nozzles, to significantly improve the treatment of the wastewater within the lagoon.

The placement of the Waving Biomedia and water/air injection system, **which will be used with the 4 aerators currently operating in the first lagoon**, will be based on a better assessment of sludge depth and its locations within the first lagoon.

Budgetary cost for microbubble aeration, which
consists of the external, self-priming pump, piping
(6 in. PVC diameter) to carry the 1,100 gpm water recycle
flow, nozzles and specially-designed venturi system,
with PLC controls ………………………………………………………… $167,200

Waving Biomedia, 17.5 ft height, 1,200 pieces at $100/piece ………….. $120,000

Total Budgetary cost, which does not include
installation, shipping and commissioning ………………………………..$287,200

Yearly cost of Enzyme-Tomahawks,
which will be needed for only two years ……………………………….. $ 4,000/yr

Cost of Enzyme-Tomahawks in subsequent years will depend on the sludge layer thickness Reduction, as measured after 1 year of using the enzyme sticks.

Payment Plan:

Purchase Order with 30% down payment

30% Payment after Water Warriors has certified to have received all materials

30% Payment before shipment of treatment system

Final Payment after installation and commissioning

COST JUSTIFICATION

Currently the operating costs with the existing aerators are as follows:

Aeration cost:	$63,000

The estimated additional operating costs with the proposed microbubble aeration system will be as follows:

Electrical cost for recycle pump at $0.08/kWh:	$15,000
Enzyme-Tomahawks:	$ 4,000 for first year

Costs for subsequent years will depend on sludge layer reduction after the first year.

Total estimated operating cost for proposed system	$19,000

There are other significant benefits that have not been monetized. These benefits are as follows:

1. Improved performance in terms of reducing 5-day BOD and TKN in the effluent and meeting the required pollutant discharge limits; and

2. Reduction in sludge blanket over the two year time period, which will increase lagoon capacity substantially and reduce the generation of TKN in the effluent due to anaerobic decomposition of the sludge blanket; For example, in a 37 acre lagoon (depth of 12 ft) treating 12 MGD of wastewater, reduction of sludge blanket by 0.6 ft resulted in 41% increase in capacity, while the dredging cost was over $700,000, which did not include sludge dewatering and disposal.

COMPARISON WITH COMPETITIVE PROPOSAL

There are several distinct advantages of using Water Warrior's aeration system rather than submerged aeration, and these advantages includes:

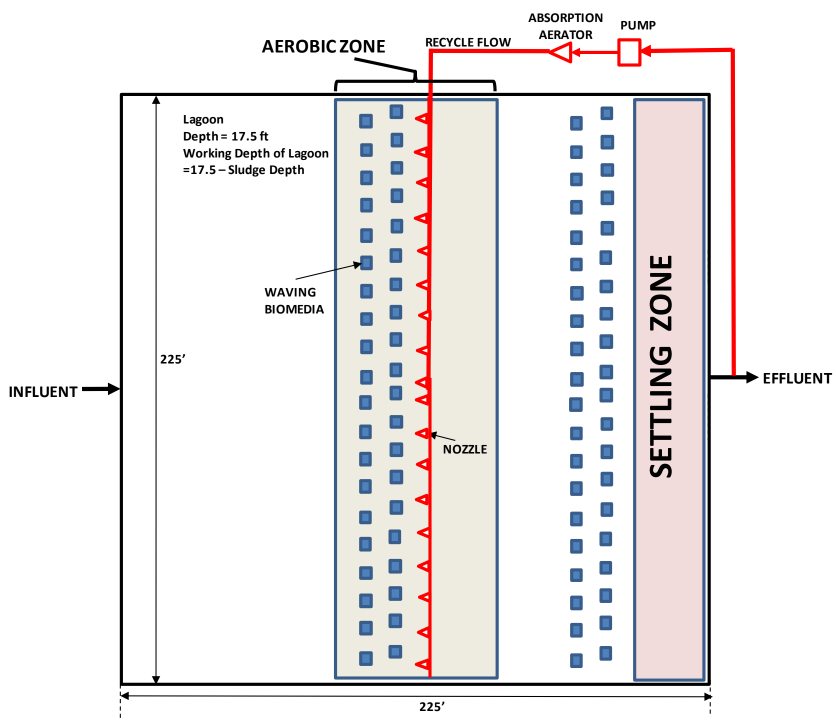
1. Submerged aeration uses small bubbles, but the average residence time of these bubbles is at the maximum a few minutes, which limits the oxygen transfer possible; Water Warrior's microbubble aeration system generates air bubbles which are 50 microns in diameter and less, and these bubbles persist in the water column for hours; more information on the microbubble aeration system is attached in the Appendix;

2. Submerged aeration needs to be periodically cleaned if there is a sludge blanket at the bottom of the existing lagoon; Water Warrior's microbubble aeration uses a mixture of air and water and injects it into the lagoon a few inches from the top of the lagoon, and hence it requires no periodic cleaning; also the use of water and air mixture not only aerates the entire water column, but also creates intense mixing within the water column, which greatly improves oxygen transfer efficiency and sludge digestion rates;

3. The amount of oxygen transferred required is 72 lbs of additional oxygen (in addition to the current aerators), and transferring this large amount of oxygen using submerged aeration would require large blowers, with substantial operating (electrical) costs; and

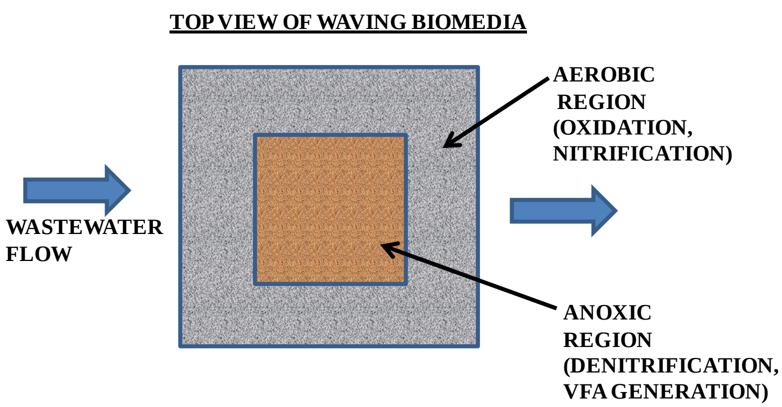
4. Additional oxygen is needed to aerobically digest the sludge blanket layer existing at the bottom of the lagoon; dissolved oxygen in conjunction with the Enzyme Tomahawks, will greatly accelerate the sludge breakdown and aerobic digestion process.

Water Warrior's proposed design is schematically shown below:



The Waving Biomedia and Microbubble aeration nozzles will be installed in one of the two identical lagoons, as shown above. The Waving Biomedia pieces will be placed within the lagoon, at an average distance of 2 ft. There will be about 100 Waving Biomedia pieces per row and hence 600 pieces will occupy 6 rows (only two rows shown in the aerobic zone in the figure above). The microbubble aeration nozzles will be placed against the flow direction to create mixing and the air/water mixture injected from the nozzles will provide the dissolved oxygen needed for aerobic treatment. The location of the nozzles and Waving Biomedia is the aerobic zone, where active treatment of the contaminants and oxidation of the ammonia to nitrates will occur.

Following the aerobic zone, there will be a zone where there is no aeration, but Waving Biomedia (6 rows with 100 Waving Biomedia pieces per row; only two shown in the figure above to maintain clarity) will be placed to allow anoxic decomposition of the nitrates to nitrogen gas through the denitrification process. The figure below shows the mechanism how the Waving Biomedia is effective for nitrification in the aerobic zone and denitrification in the anoxic zone.



The outer region of the biomedia is aerobic due to diffusion of dissolved oxygen, while the inner region remains anoxic due to inability of dissolved oxygen to penetrate this region, since it gets consumed in the aerobic region. In the aerobic region, oxidation of BOD and nitrification of ammonia to nitrate will occur, while in the anoxic region, denitrification of nitrates to nitrogen gas and generation of Volatile Fatty Acids (VFAs) will occur. VFAs or Volatile Fatty Acids, generated by anoxic decomposition of sludge and organics reacts with phosphorus to form a polymer, which precipitates within the lagoon in the settling zone.

Following the anoxic zone, there is a settling zone, where the suspended solids and biomass flocs will settle down due to lower water velocity (0.007 ft/min average velocity). **This will negate the need for a clarifier after the water exits the lagoon with the proposed modifications.**

The main advantages of the proposed lagoon modifications are as follows:

1. A significantly advanced aeration system which uses microbubbles rather than submerged aeration to provide dissolved oxygen at a significantly higher oxygen transfer efficiency than any comparable submerged bubble aeration;

2. The use of Waving Biomedia increases active biomass concentration by a factor of four (4) to six (6) times the suspended biomass concentration in a lagoon, and this substantially increases the rate of biodegradation of the contaminants within the lagoon; due to this accelerated treatment capability by the Waving Biomedia, only one lagoon will be needed to handle the wastewater flowrate instead of the existing two lagoons; In addition, Waving Biomedia allows nitrification and denitrification to occur in addition to phosphorus removal;

3. Waving Biomedia is significantly better than submerged fixed-film plastic media, since it does not clog over time due to biomass growth; submerged plastic media structures grow biomass gradually and eventually prevent water from flowing through the submerged plastic structure;

4. The proposed modifications are all made to one of the existing lagoons and does not require any post-processing reactor to meet the desired effluent limits; the use of Waving Biomedia, Microbubble Aeration and Enzyme Tomahawks works synergistically to reduce the sludge blanket layer, thereby increasing the treatment efficiency of the lagoon, while meeting the desired effluent limits.

SCOPE OF SUPPLY

The Scope of Supply for this project will be as follows:

Material / Equipment Item/Work to be Completed	WATER WARRIORS' Scope	Buyer Scope
A. RECYCLE PUMP		
1,100 gpm, 60 psi (21 kW) self-priming, centrifugal pump, stainless steel	X	
6 inch PVC Sch 80, approx 4 ft length water inlet pipe with screen	X	
B. ABSORPTION AERATOR + WAVING BIOMEDIA + ENZYME TOMAHAWKS		
One 8 inch size Absorption Aerator with air inlet check valves (2); 1,200 pieces of Waving Biomedia, each 17.5 ft height; Supply of Enzyme Tomohawks	X	
C. WATER DISTRIBUTION PIPES		
Three lengths of 6 in PVC Sch 80 pipes, painted twice with UV resistant paint, , connected to header Flange fittings for each 10 ft length of pipe with nozzles mounted on T- joints Flange fittings to pump and header, and header pipes	X	
D. CONTROL BOX		
NEMA 4X control box with pump start/stop, power connection,	X	
and breaker; Wiring in conduit to pump	X	
Control box mounted on skid	X	
E. SKID		
Skid size will be 16 ft x 16 ft	X	
Pump will be wired to control box	X	
Skid will have pump, Absorption Aerator, Control valve and Control Box mounted	X	
F. INSTALLATION		
Installation of supplied piping along length of lagoon with mechanical supports		X
Installation of skid and power connection to skid		X
Installation of inlet piping into lagoon		X

DRAWINGS/DOCUMENTATION

After receipt of official purchase order and all applicable specifications, orientations, and subject to sub-vendor drawing availability, PCC will submit the following drawings & documents as indicated:

Drawing & Document Description	E-Copy	Submitted As				Wks ARO	Wks ARA	Notes
		A	C	R	I			
Phase 1 Submittal:								
Project Schedule (preliminary)	1				X			
General Arrangement	1	X						
Flow diagram	1	X						
Equip. Anchor Bolt /Loading	1	X						
Customer Approval Cycle								
Phase 2 Submittal:								
Equipment data sheets	1				X			
Wiring Diagram	1				X			
External Panel Layout	1				X			
Customer Approval Cycle								
Phase 3 Submittal: Certified for Construction			X					
All Phase 1 & Phase 2	1			X				
Spare Parts List	1			X				
Additional Submittals:								
Installation, Operation, and Maintenance Manuals	2 hard copies			X				

Submittal Legend:
A = For Approval : **C** = Certified : **R** = For Record Only : **I** = For Information Only
ARO = After Receipt of Order : **ARA** = After Receipt of Approval

SERVICES

A variety of field services are available upon request. Water Warriors, LLC can supply equipment installation, installation supervision, start-up/commissioning services, operator training and routine equipment service, as needed. These services can be purchased with the equipment or they can be purchased at a later date as needed.

Since installation is by others, Water Warriors will provide detailed installation instructions for the aeration and Waving Biomedia system. Once the system is installed at the site, a site visit to check the installation of the aeration pipe within the sump and checking the mixing of the tank by the air and the movement of the biomedia within the sump will be arranged by Water Warriors' representative.

This installation and operational checking usually takes about 2 days at the maximum. Start-up services usually take about 1 day and at a maximum of 2 days. Water Warrior has included two (2) days of service and expenses at NO CHARGE.

EXCLUSIONS

Specifically excluded from this proposal are any components or services unless itemized in this quotation. Water Warriors will be glad to add additional scope to our supply at your request.

- Foundations, installation, shipping and off-loading equipment.
- Electrical supply, step down transformers, motor starters, and field wiring.
- All utilities, interconnecting (field) piping, ducting, and all pipe supports
- Any field labor or modification changes on account of work performed on our equipment unless prior approval in writing by an authorized Water Warrior engineer.
- Freight, water testing and any required permits.
- All required platforms, ladders and stairs.
- Installation of pipe in Lagoon, six inches below water level
- Field joints in the aerator pipes
- Permit costs
- Shipping costs

WATER WARRIORS TEAM

WATER WARRIORS, LLC (WATER WARRIORS) has the experience needed for designing advanced water treatment systems.. Our broad spectrum of applications includes chemical, petrochemical, industrial, mineral, wood products, carbon products, pharmaceutical, automotive, and many other applications.

WATER WARRIORS founders has executed several projects worldwide and is headquartered in Cincinnati, Ohio. We offer our worldwide customers the following benefits:

- Strong process design using ASPEN Modeling and 20+ years experience
- Custom design to suit project requirements
- Complete system integration experience
- Strong project management & engineering team
- Strong after market service team
- Respected industry reputation
- Guaranteed system performance

WATER WARRIORS has also developed the Oil Eraser product, which is used to pick up oil from water, as in an ocean oil spill. It has been in the business of designing and supplying biomedia systems. The founder of WATER WARRIORS Tech, Inc., Dr. Rakesh Govind, pioneered several pollution treatment system design using synthetic media and has published over 35 papers on the topic of biomedia for treating a wide variety of contaminants. Dr. Govind and designed and supplied pollution treatment systems for treatment of odors and volatile organic compounds to private companies and municipalities in the US, Canada, Europe and other countries. The biomedia systems supplied have varied in size from 200 -300,000 acfm.

APPENDIX

ADDITIONAL INFORMATION ON MICROBUBBLE AERATION, WAVING BIOMEDIA AND ENZYME TOMAHAWKS

ABSORPTION AERATOR – COST-EFFECTIVE AERATION SYSTEM

An aeration system is among the most energy-intensive operations in wastewater treatment systems and is responsible for between 50-90% of total energy consumption in typical municipal installations. The optimum bubble size for aeration with compressed air and no mechanical mixing typically is considered to be 1 to 2 mm in diameter. This range of bubble diameter provides a compromise between the conditions for good mass transfer and efficient mixing. Gas transfer technologies that are able to produce bubbles in the range of 10 to 1000 μm require a high power input, such as fine bubble aeration, jet aeration, etc. For standard submerged aerators, the bubble formation on the surface of aerator undergoes three stages: expansion stage, detachment stage, and coalescence due to bubble-bubble combination, which results in larger bubbles.

The transfer of oxygen from the air bubble to the water depends on wastewater characteristics: (1) concentration of soluble salts (Total Dissolved Solids or TDS), water temperature, water depth, total suspended solids (TSS), presence of surface active agents, etc.; (2) tank geometry, bubble size, kinetic energy of the fluid, etc.; and (3) extent and type of liquid mixing with the bubbles, which determines the path length of the air bubble.

The Actual Oxygen Transfer Rate (AOTR) = Standard Oxygen Transfer Rate (SOTR) x α x β x φ

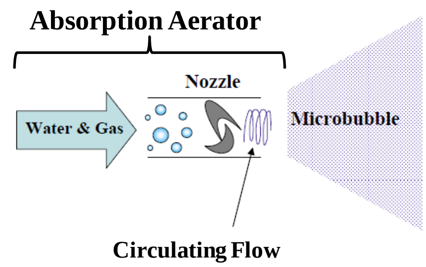
where SOTR is the oxygen transfer rate for pure water, α is the parameter that depends on the type of aeration device, intensity of mixing and tank geometry, β is the parameter that corrects for TDS, TSS, concentration of surface active agents, and φ is the parameter that adjusts for the oxygen solubility as a function of water temperature.

Table 1 lists the SOTR values for typical aerators, including the Absorption Aerator aeration system.

Type of Aeration System	SOTR Value (lbs oxygen/hp/hr)
Surface Aerator with draft tube	1.2 – 2.1
Surface high speed	1.2 – 2.0
Submerged turbine	1.0 – 2.0
Submerged turbine with sparger	1.2 – 1.8
Surface brush and blade	0.8 – 1.8
Fine bubble diffusers	0.5 – 1.5
Coarse bubble diffusers	0.3 – 0.8
Absorption Aerator	2.7 – 3.1

The Absorption Aerator's basic mechanism is to pump liquid water through a specially designed nozzle in which the high velocity of the liquid combined with swirl flow creates a negative pressure that draws in ambient air which is dispersed in the form of microbubbles (less than 50 μm in diameter). Figure 1 shows the basic schematic of the Absorption Aerator with its microbubble generation mechanism.

Figure 1. Basic mechanism of the Absorption Aerator.



The Absorption Aerator has a high oxygen transfer efficiency due to the following factors: (1) high gas/liquid ratio = 2.2:1.0;
(2) high intensity of mixing in the nozzle system; (3) no external blower required, which has major maintenance requirements;
(4) the microbubbles have a large residence time within the water, thereby allowing the dissolved gases in the water, such as carbon dioxide, hydrogen sulfide, etc. to be effectively stripped out; and
(5) 50 μm or smaller bubbles ultimately dissolve completely, creating an implosion that creates hydroxyl radicals; these radicals effectively treat the contaminants in the water, such as hydrolysis of fats and oils, oxidation of ammonia, which promotes biological activity.

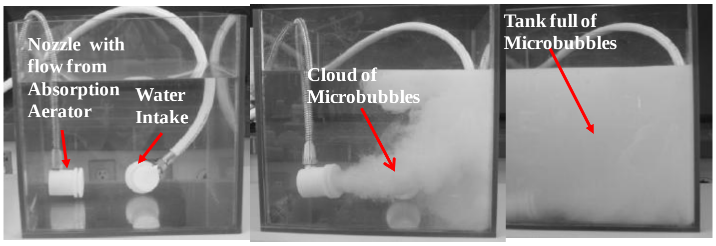
Table 2 compares the ordinary bubbles, created by sparging, surface aeration, etc with microbubbles created by the Absorption Aerator.

Table 2. Comparison of the Absorption Aerator's Microbubbles with Sparging Bubbles.

Bubble Size (μm)	Production Method	Properties
> 50	Submerged aeration, sparging, surface aeration, etc	Bubble coalesce into larger bubbles, rise quickly and break on the surface; oxygen transfer efficiency is less than 10% in clean water and less than 6% in wastewater
< 50	Absorption Aerator	Negatively charged surface of bubble prevents coalescence and bubble spends enough time within the water to achieve enhanced oxygen transfer; Once the bubble size becomes smaller than 10 μm due to air dissolution, the bubble does not rise to the surface, since its mass is balanced by its buoyancy; Microbubbles smaller than 10 μm effectively attach to submerged surfaces, thereby never rising to the water surface

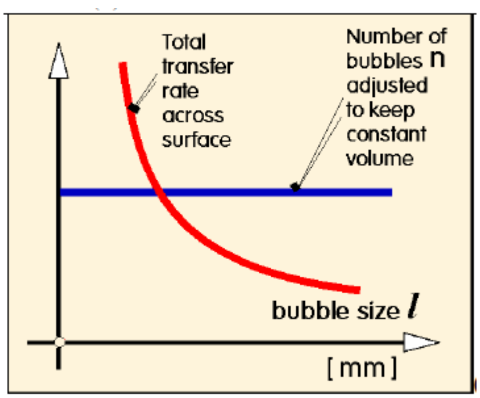
Figure 2 shows a time lapse photograph of a glass tank, in which there is water intake going to the Absorption Aerator, outside the tank, and not shown in the pictures, and the outlet nozzle, within the tank that discharges air/water mixture flow into the tank. The first picture shows the water intake and discharge nozzle, the second picture shows the onset of microbubbles leaving the discharge nozzle and the last photograph shows the tank filled with microbubbles of air.

Figure 2. Photographs showing the generation of microbubbles using the Absorption Aerator.



For a fixed volume of air, the surface area of the bubbles increases proportional to 1/*ℓ*, as the diameter of the bubble (*ℓ*) decreases, and this is shown in Figure 3.

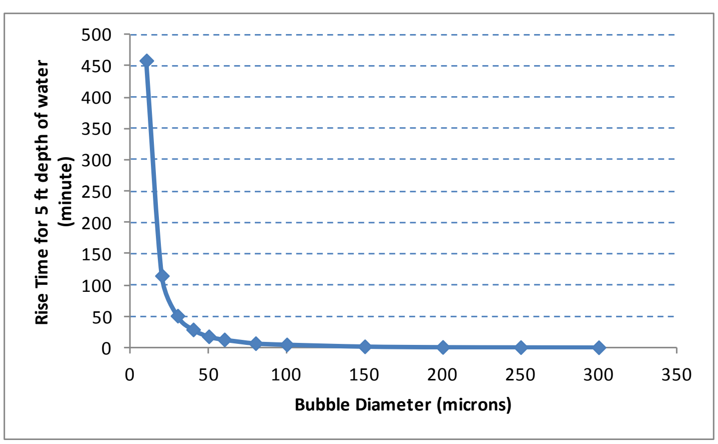
Figure 3. Increase in surface area as a function of bubble diameter (*ℓ*) for a fixed air flowrate.



Clearly, as the bubble diameter decreases, the total transfer rate of oxygen across the bubble interface increases, due to increases in bubble area.

The bubble rise (residence time) for a water depth of 5 ft has been calculated as a function of bubble diameter, and this is shown in Figure 4.

Figure 4. Bubble Rise Time through water depth of 5 ft. as a function of Bubble Diameter.



As the bubble size decreases below 50 microns (microbubbles), the rise time begins to increase rapidly for a tank with 5 ft depth of water. The above curve was constructed assuming that the water density is constant. However, as the bubble rise time increases, the density of the air-water mixture decreases, since at 70 deg F the density of air is 0.07 lb/ft3 while the density of water is 62.3 lbs/ft3. This decrease in air-water mixture density decreases the buoyancy of the bubble, and slows down its rise rate through the water.

Pond/Lake Aeration System

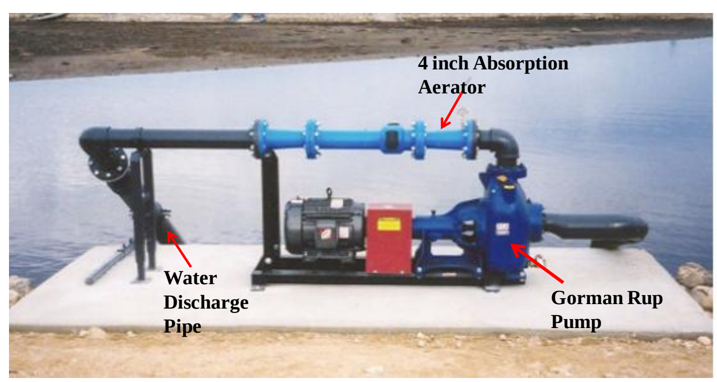
Anoxic conditions prevail in most ponds/lakes due to oxygen consumption by the microorganisms that are consuming contaminants from surface water run-off into the pond. These surface water run offs usually contain insecticides, fertilizers, etc. that result in a variety of growths within the water that consume oxygen. Typically, the rate of oxygen transfer from the water surface is small, unless the water is actively recirculated.

Figure 5 shows the intake of a pond/lake water aeration system, from which water is drawn in by a pump, located outside the water and on the side of the pond. This water intake pipe is usually perforated and located above the bottom to prevent the suction of bottom sediment.

Figure 5. Intake Manifolds (red color perforated pipes), located above the bottom of the lake/pond, for an Absorption Aerator System.

Figure 6 shows an Absorption Aerator system for a pond aeration, in which water is taken from one end of the pond through intake pipes (not shown in the photograph), and then pumped through the Absorption Aerator, wherein it mixes with the ambient air that is drawn in by the water flow, and then this water with microbubbles is discharged back into the pond through discharge nozzles (not shown).

Figure 6. Photograph of an Absorption Aerator system for a pond.



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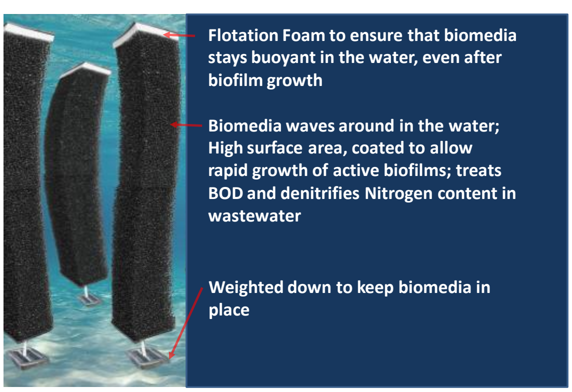
Cincinnati, OH 45212

WAVING BIOMEDIA – TECHNOLOGY SHEET

Waving Biomedia was developed as a hybrid between fixed and moving biomedias. Fixed biomedia is typically placed inside the lagoon or treatment system, and consists of plastic plates, bonded together to form a high surface area structure. The main issue with fixed biomedia is with respect to growth of biomass and deposition of suspended solids that eventually results in clogging of the biomedia, and the liquid flow begins to by-pass the fixed media, which decreases treatment efficiency. Moving biomedia, consists of small 1 in diameter plastic pieces, which are neutrally buoyant, and grow biofilms on their surface. Typically 50-60% of treatment volume is occupied by the moving media, which reduces treatment capacity substantially and these plastic pieces have to be retained using a screen at the exit of the treatment zone. In addition, due to the large number of plastic pieces, the biofilms abrade off the outside surfaces and their ability to retain effective biofilms is limited.
For both fixed and moving biomedias, the hydraulics of the liquid flow is very critical, in order to maintain treatment effectiveness.

Waving Biomedia stays in place, since it is weighted down, and it waves around in the water, instead of moving around. This gives the biomedia from accumulating suspended solids, like fixed biomedia, and its movement is independent of the hydraulics and mixing effectiveness, as is the case with moving biomedia. No screens are required to retain this biomedia, since the biomedia remains in place, and unlike fixed biomedia structure, it is simply placed within the lagoon or treatment system, since each biomedia piece is weighted down enough to keep it in one place.

Schematic of the Waving Biomedia is shown below.



Waving Biomedia in water.

Nitrification/Denitrification

Waving biomedia is engineered to grow active biofilms, for treating organic contaminants and for nitrification and denitrification, as in the case of ammonia treatment. This biomedia, unlike other biomedias, is designed to create aerobic conditions on the outside area of the biomedia to nitrify the ammonia to nitrate/nitrite and anoxic conditions on the inside of the biomedia, in order to denitrify the nitrate/nitrite to nitrogen gas. The biomedia has a chemical coating on the surface of the foam material which enables rapid attachment of the active biofilms. In typical uncoated biomedias, biofilm attachment and growth can take considerable time, while in our coated biomedias, full biofilm growth is usually achieved in a few hours. In addition, 10% of the media can be supplied with **biomass pellets** that contain organisms (aerobic bacteria, nitrifiers/ denitrifiers), to seed the bed during start-up. This allows faster start-up of the biobeds, especially since nitrifiers and denitrifiers are slow growing organisms. Furthermore, biofilm attachment of these slow growing organisms prevents washout, which is a common problem with suspended culture bioreactors. In addition, the attached biofilms increase active biomass concentrations in the biobeds five to seven-fold over suspended culture bioreactors, thereby increasing biotreatment rates substantially.

Waving Biomedia Specifications

Dimensions: 4 inches x 4 inches x Depth of water
Surface Area: 280 ft^2/ft^3
Max. BOD Treatment Rate: 0.005 lb BOD/ft^2.day
Max. TKN Treatment Rate: 0.004 lb TKN/ft^2.day
Nominal distance between pieces: 2 feet
Arrangement: Staggered to allow water to contact the pieces, as much as possible
Location: Near or soon after aeration, to maximize dissolved oxygen in the flowing water

Performance of Waving Biomedia

Waving Biomedia, about 47 inches in height, were placed in an Advanced Septic Tank, which was treating household sewage at a maximum flowrate of 1200 gallons per day. The water was also aerated using a proprietary microbubble aeration method that maintained a dissolved oxygen level in excess of 4 mg/L. The size of the tank is 1530 gallons and average wastewater influent flowrate was 600 gpd. There were a total of 30 Waving Biomedia Pieces in this tank, for a total biomedia surface area of 104 ft^2. Performance of this system is given below in the table.

Water Quality Parameter	Influent	Effluent from NextGen Septic Tank
Biological Oxygen Demand (mg/L) cBOD5	450	3.4
Volatile Suspended Solids (mg/L)	148	2.7
Turbidity (NTU)	89	0.02
Nitrate – N (mg/L)	129	9.1
Total Organic Carbon (mg/L)	280	4.1
Ammonia- N (mg/L)	56	< 0.1
Total Suspended Solids (mg/L)	110	Below Detection Limits
Fecal Coliform (CFU/100 mL)	9.48×10^6	3.0

The performance of the system is after the Ultrafiltration membrane separation of the solids, which was mainly responsible for major reductions in suspended solids, turbidity and Fecal Coliforms. However, the majority of cBOD reduction, Ammonia and nitrates were due to biological treatment of the wastewater due to the immobilized cultures within the Waving Biomedia. Reductions in ammonia and nitrate were due to nitrification and denitrification, occurring within the biomedia structure.

Cost

Waving Biomedia is priced at $40 per piece for a total height of 6 ft, which includes the complete assembly including the weight at the bottom. The cost is higher with increasing length for greater depths of water.

Microbubble Aeration

The transfer of oxygen from the air bubble to the water depends on wastewater characteristics: (1) concentration of soluble salts (Total Dissolved Solids or TDS), water temperature, water depth, total suspended solids (TSS), presence of surface active agents, etc.; (2) tank geometry, bubble size, kinetic energy of the fluid, etc.; and (3) extent and type of liquid mixing with the bubbles, which determines the path length of the air bubble.

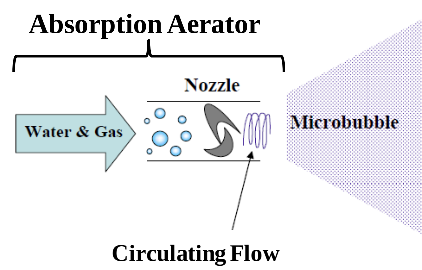
The Actual Oxygen Transfer Rate (AOTR) =
Standard Oxygen Transfer Rate (SOTR) x α x β x φ

where SOTR is the oxygen transfer rate for pure water, α is the parameter that depends on the type of aeration device, intensity of mixing and tank geometry, β is the parameter that corrects for TDS, TSS, concentration of surface active agents, and φ is the parameter that adjusts for the oxygen solubility as a function of water temperature.

Table 1 lists the SOTR values for typical aerators, including the Absorption Aerator aeration system.

Type of Aeration System	SOTR Value
Surface Aerator with draft tube	1.2 – 2.1
Surface high speed	1.2 – 2.0
Submerged turbine	1.0 – 2.0
Submerged turbine with sparger	1.2 – 1.8
Surface brush and blade	0.8 – 1.8
Fine bubble diffusers	0.5 – 1.5
Coarse bubble diffusers	0.3 – 0.8
Absorption Aerator	2.7 – 3.1

The Absorption Aerator's basic mechanism is to pump liquid water through a specially designed nozzle in which the high velocity of the liquid combined with swirl flow creates a negative pressure that draws in ambient air which is dispersed in the form of microbubbles (less than 50 μm in diameter). The Figure below shows the basic schematic of the Absorption Aerator with its microbubble generation mechanism.



Potential Applications

Waving Biomedia with and without microbubble aeration can be applied in many treatment applications:

- Liquid-phase bioreactors – aerobic or anaerobic
- Lagoons, for treating wastewater
- Sequential Batch Reactors (SBRs) treating wastewater
- Activated Sludge aeration basins
- Biogas digesters – will generate more biogas

For more information, please contact:

Dr. Rakesh Govind, President, PRD Tech, Inc.
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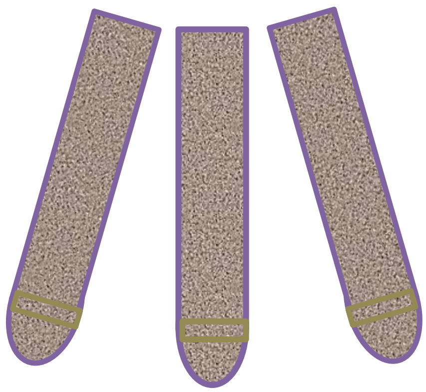
ENZYME TOMAHAWKS – TECHNOLOGY SHEET
Alternative to Lagoon Dredging



Enzyme Tomahawks are solid spikes composed of billions of microorganisms, biosurfactants, enzymes and nutrients, that enable accelerated biodegradation of the sludge layer, at the bottom of the lagoon. Enzyme Tomahawks are simply dropped above the water level, that causes them to penetrate the sludge layer at the bottom of the water column. Once lodged inside the sludge, the Enzyme Tomahawks slowly release their microorganisms, biosurfactants and enzymes within the sludge layer.

Benefits

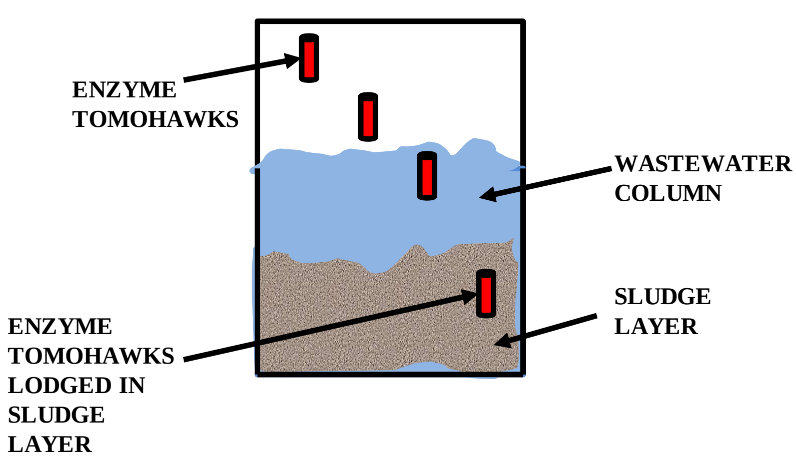
The main benefits of using Enzyme Tomahawks are:

- Eliminates sludge dredging, which saves substantial cost;
- Increases lagoon capacity, by reducing sludge layer thickness;
- Decreases by-passing of wastewater around the thicker sludge layers within the lagoon;
- Eliminates anoxic decomposition of the sludge layer which releases Volatile Fatty Acids (VFAs) and ammonia into the effluent;

- Can be used without interrupting lagoon operation; and
- Incurs minimal cost and installation time.

The schematic below shows the installation of Enzyme-Tomahawks. Each enzyme stick is dropped above the water column, with approximately 1-2 ft distance between them.

LAGOON SIDE VIEW



Enzyme Tomahawks are used in conjunction with aeration and mixing to provide dissolved oxygen to the microorganisms being released by the Enzyme Tomahawks. Aerobic decay is substantially faster than anoxic decomposition.

Enzyme Tomahawks contains aerobic and facultative bacteria that produce powerful digestive enzymes (cellulases, hemicellulases, amylases, proteases and lipases) that break down the organic matter in the sludge layer. In addition, they contain enzymes which promote bio-chemical processes that reduce odor and preserve fertilizer type nutrients (N, P & K) either by converting odiferous compounds into microbial protein or by suppressing the activities of the bacteria that produce foul odors. They also contains powerful oxygenating compounds and surfactants to optimize microbial activity, and contains micronutrients and growth stimulants to ensure rapid activation of microbial activities.

In one application treating a 30 ft x 130 ft section of a lagoon, sludge level was reduced by 38% in 30 days. The dosing rate of Enzyme Tomahawks depends on the influx rate of solids into the lagoon. If the solids deposition rate is unknown, the maximum number of Enzyme Tomahaewks are placed in the sludge layer at a distance of 1 ft. Once partial sludge layer decay has been achieved in the first year, depending on this rate of decomposition, the distance between the Enzyme Tomahawks, placed within the sludge layer, can be increased to 2 ft. After an average sludge layer thickness of less than 2 ft has been achieved, the use of Enzyme Tomahawks can be discontinued, if there is sufficient dissolved oxygen to maintain a high rate of sludge decay rate within the lagoon.

Field Application

The pulp and paper industry relies heavily on aerobic biological treatment processes to remove biodegradable organics (BOD_5), suspended solids, and pollutants that can cause bioassay-measured toxicity. Effective aeration systems are an essential part of any aerobic wastewater treatment system, providing oxygen for aerobic bacterial growth and mixing. Over time, pulp and paper mills typically see reduced biological treatment performance resulting from sludge build up in lagoons. The build up of sludge leads to reduced lagoon capacity, inadequate oxygen supply, and mixing. Beyond inefficient water treatment processing and higher energy costs, this can result in non-compliance with NPDES permit discharge limits and potential fines and penalties.

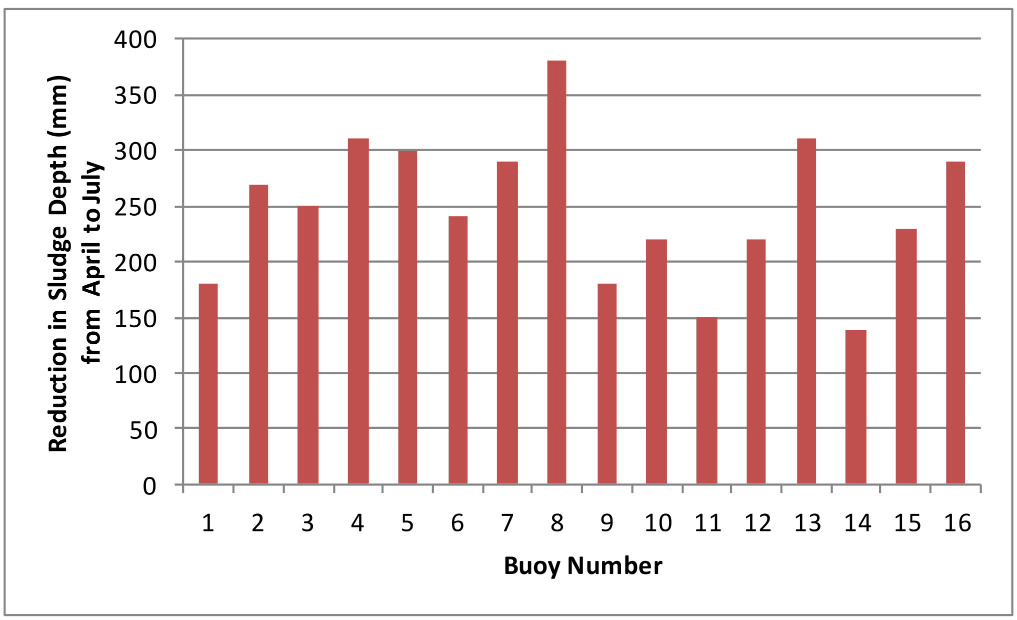
Even though new aerated lagoons are designed with extra volume to provide adequate treatment time as sludge is deposited over time, eventually the loss of volume and HRT limits performance. Treatment volume and residence time must be restored by removal of sludge deposits. Sludge removal by dredging and dewatering is a very expensive process, in the range of $200/dry ton of solids if mechanical dewatering is employed, *not* including costs for final disposal in a landfill or by some other option.

A large pulp and paper mill in the Southeastern US had significant biosolids accumulation in the quiescent zone of their Aerated Stabilization Basin that hindered treatment plant efficiency and performance. The wastewater system consisted of a primary clarification system with sludge removal via belt press located near the mill site that captures fiber and TSS from the combined paper and pulp mill effluent streams and a secondary biological treatment system located approximately 2.4 km west of the facility.

The primary clarifier effluent was pumped to an inlet box at the secondary treatment system and fed into the first run of the aerated stabilization basin. The 165,921 m^2 Aerated Stabilization Basin had three aeration zones, separated by curtains that caused the flow to serpentine through the system. 32 surface mounted aerators with 2,400 total connected horsepower supplied dissolved oxygen to the biological treatment system. After aerated treatment, wastewater flows through a quiescent zone 762 meters long and 91 meters wide (69,342 m^2) . This quiescent zone was designed to allow sludge to accumulate in the basin while treated effluent passed to the final outfall.

Enzyme Tomahawks were placed within the sludge layer of the quiescent zone area, two feet apart from each other, in areas with significant sludge depth. Sixteen buoys were installed in the quiescent zone area (762 m long and 91 m wide), and measurements of clear water depth were made between April and July. The figure below shows the change in sludge depth (in mm), over a four month time period, for the 16 locations within the quiescent zone area.

The average sludge depth reduction was 247 mm, which resulted in almost 17,000 m^3 of sludge destruction over the four month time period. This saved substantial dredging cost for the mill in addition to costs associated with dewatering and landfill disposal of the sludge.



For more information about Enzyme Tomahawks and their possible application within your Lagoon, please contact: Dr. Rakesh Govind, Water Warriors, LLC, 1776 Mentor Avenue; STE 400A, Cincinnati, OH 45212; Tel: (513) 673 3583; Email: rgovind837@aol.com

LAGOON WATER TREATMENT

Lagoons are pond-like bodies of water or basins designed to receive, hold, and treat **wastewater** for a predetermined period of time. If necessary, they are lined with material, such as clay or an artificial liner, to prevent leaks to the groundwater below. In the lagoon, wastewater is treated through a combination of physical, biological, and chemical processes. Much of the treatment occurs naturally, but some systems use aeration devices to add oxygen to the wastewater. **Aeration** makes treatment more efficient, so that less land area is necessary. Aerators can be used to allow existing systems to treat more wastewater.

Dissolved oxygen is present throughout much of the depth of aerobic lagoons. They tend to be much shallower than other lagoons, so sunlight and oxygen from air and wind can better penetrate the wastewater. In general, they are better suited for warm, sunny climates, where they are less likely to freeze. Wastewater usually must remain in aerobic lagoons from 3 to 50 days to receive adequate treatment. Wastewater treatment takes place naturally in many aerobic lagoons with the aid of aerobic bacteria and algae. Because they are so shallow, their bottoms need to be paved or lined with materials that prevent weeds from growing in them.

Aerated lagoons are common in small communities. These systems use aerators to mix the contents of the pond and add oxygen to the wastewater. They are sometimes referred to as partial-mix or complete-mix lagoons depending on the extent of aeration. Partial-mix aerated lagoons are often anaerobic lagoons that have been adapted and upgraded to receive more wastewater.

Facultative Lagoons

Like most natural environments, conditions inside facultative lagoons are always changing. Lagoons experience cycles due to variations in the weather, the composition of the wastewater, and other factors. In general, the wastewater in facultative lagoons naturally settles into three fairly distinct layers or zones. Different conditions exist in each zone, and wastewater treatment takes place in all three.

The top layer in a facultative lagoon is called the aerobic zone, because the majority of oxygen is present there. How deep the aerobic zone is depends on loading, climate, amount of sunlight and wind, and how much algae is in the water. The wastewater in this part of the lagoon receives oxygen from air, from algae, and from the agitation of the water surface (from wind and rain, for example). This zone also serves as a barrier for the odors from gases produced by the treatment processes occurring in the lower layers.

The anaerobic zone is the layer at the very bottom of the lagoon where no oxygen is present. This area includes a layer of sludge, which forms from the solids that settle out of the wastewater. Here, wastewater is treated by anaerobic bacteria, microscopic organisms, such as certain protozoa, and sludge worms, all of which thrive in anaerobic conditions.

Names for the middle layer include the facultative, intermediate, or aerobic-anaerobic zone. Both aerobic and anaerobic conditions exist in this layer in varying degrees. Depending on the specific conditions in any given part of this zone, different types of bacteria and other organisms are present that contribute to wastewater treatment.

Throughout facultative lagoons, physical, biological, and chemical processes take place that result in wastewater treatment. Many of these processes are interdependent. For example, on the surface, wind and sunlight play important roles. Surface agitation of any kind adds oxygen to the wastewater. For this reason, facultative lagoons are designed to make the best use of wind in the area.

Mixing of Water in Lagoons

Mixing and aeration of water in the lagoon is important to prevent algae growth. Without mixing thermo stratification will occur, thereby permitting the retention of undisturbed surface layers for relatively long periods of time. Such conditions provide an excellent environment for algae to become established and grow.

Relevance of Nitrification and De-nitrification in Lagoons

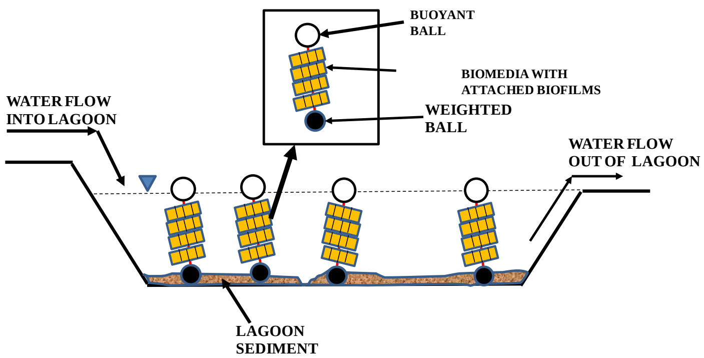
Nitrification is the process of converting the ammonium in the water to nitrates/nitrites. Some **nitrification** generally occurs in most **aerated lagoons**. However, such nitrification is usually unpredictable and cannot be depended upon to meet effluent limits, especially during the winter months. Therefore, for aerated lagoons to be considered as viable processes for nitrification, the lagoon process must be modified so that the solids age is uncoupled from the hydraulic retention time (HTR).

To enable efficient nitrification and subsequently de-nitrification, which is the conversion of nitrates/nitrites to nitrogen gas, and to decouple the solids age from the Hydraulic Retention Time (HRT), the use of biomedia in the lagoon is very important. This biomedia, which has a high surface area, enables biofilms to grow on the surface of the biomedia, and this attached biomass stays in the lagoon for a very long time, i.e., almost infinite solids age, while the water continues to flow through the lagoon, at its Hydraulic retention time. This allows the solids age to be decoupled from the lagoon's HRT.

Application of Biomedia in Lagoons

PRD Tech, Inc., Inc. has pioneered a unique biomedia that has a very high surface area, that stays within the lagoon water. It consists of a cable, with a heavy weight at the bottom and a flotation balloon at the top. This cable is threaded through biomedia plates, thereby allowing the biomedia to move in a wave-like fashion without flowing with the water. Since the cable is threaded through the cable, which stays in place due to its weight at the bottom, the biomedia moves around but essentially stays in a given location. This allows the water to be treated by the biofilms that coat the biomedia, as it waves around in the water. Figure 1 shows the biomedia within the lagoon water.

Figure 1. Schematic showing the Biomedia in the Lagoon Water.



In addition, the biofilms on the surface of the biomedia allow nitrification and de-nitrification of the water, as it flows past the biomedia, that is waving around in the water. This allows effective water treatment, without pumping the water out of the lagoon.

Aeration and Mixing of Lagoon Water

The transfer of oxygen from the air bubble to the water depends on wastewater characteristics: (1) concentration of soluble salts (Total Dissolved Solids or TDS), water temperature, water depth, total suspended solids (TSS), presence of surface active agents, etc.; (2) tank geometry, bubble size, kinetic energy of the fluid, etc.; and (3) extent and type of liquid mixing with the bubbles, which determines the path length of the air bubble.

The Actual Oxygen Transfer Rate (AOTR) = Standard Oxygen Transfer Rate (SOTR) x α x β x φ

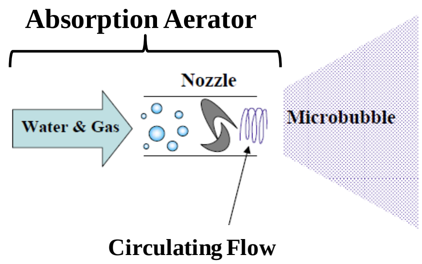
where SOTR is the oxygen transfer rate for pure water, α is the parameter that depends on the type of aeration device, intensity of mixing and tank geometry, β is the parameter that corrects for TDS, TSS, concentration of surface active agents, and φ is the parameter that adjusts for the oxygen solubility as a function of water temperature.

Table 1 lists the SOTR values for typical aerators, including the Absorption Aerator aeration system.

Type of Aeration System	SOTR Value
Surface Aerator with draft tube	1.2 – 2.1
Surface high speed	1.2 – 2.0
Submerged turbine	1.0 – 2.0
Submerged turbine with sparger	1.2 – 1.8
Surface brush and blade	0.8 – 1.8
Fine bubble diffusers	0.5 – 1.5
Coarse bubble diffusers	0.3 – 0.8
Absorption Aerator	2.7 – 3.1

The Absorption Aerator's basic mechanism is to pump liquid water through a specially designed nozzle in which the high velocity of the liquid combined with swirl flow creates a negative pressure that draws in ambient air which is dispersed in the form of microbubbles (less than 50 μm in diameter). Figure 2 shows the basic schematic of the Absorption Aerator with its microbubble generation mechanism.

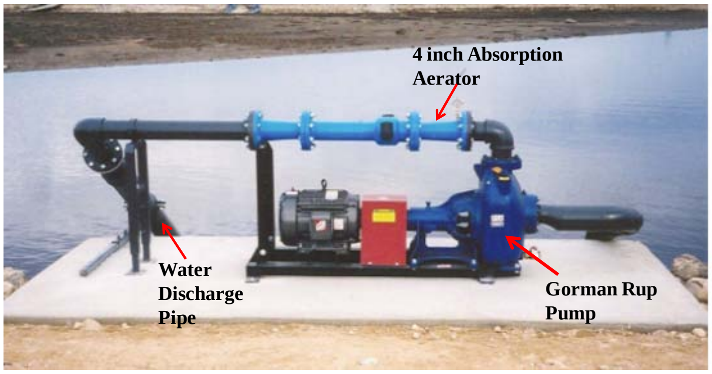
Figure 2. Basic mechanism of the Absorption Aerator.



The Absorption Aerator has a high oxygen transfer efficiency due to the following factors: (1) high gas/liquid ratio = 2.2:1.0;
(2) high intensity of mixing in the nozzle system; (3) no external blower required, which has major maintenance requirements;
(4) the microbubbles have a large residence time within the water, thereby allowing the dissolved gases in the water, such as carbon dioxide, hydrogen sulfide, etc. to be effectively stripped out; and
(5) 50 μm or smaller bubbles ultimately dissolve completely, creating an implosion that creates hydroxyl radicals; these radicals effectively treat the contaminants in the water, such as hydrolysis of fats and oils, oxidation of ammonia, which promotes biological activity.

Figure 3 shows an Absorption Aerator system for a pond aeration, in which water is taken from one end of the pond through intake pipes (not shown in the photograph), and then pumped through the Absorption Aerator, wherein it mixes with the ambient air that is drawn in by the water flow, and then this water with microbubbles is discharged back into the pond through discharge nozzles (not shown).

Figure 3. Photograph of an Absorption Aerator system for a pond.



PRD Tech, Inc. can supply a complete lagoon treatment system, which consists of the biomedia that waves around in the water, together with an Absorption Aerator system that can effectively supply oxygen to the water using microbubbles.

FOR MORE INFORMATION CONTACT
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Email: rgovind837@aol.com

PROPOSAL ON ENHANCING LAGOON WASTEWATER TREATMENT USING ADVANCED TECHNOLOGIES

Dr. Rakesh Govind
Water Warriors, LLC
1776 Mentor Avenue; SET 400A
Cincinnati, OH 45212

August 2017

EXISTING LAGOONS, BRANDENBURG, KY

Design and Operating Parameter	**Value**
Length/Width	225 ft each
Depth	17.5 ft
Flowrate	232,000 gpd Average 312,000 gpd Design 932,000 Maximum
Influent Water Parameters	
BOD (5 days)	401 mg/L 334 mg/L Design
TSS	371 mg/L 323 mg/L Design
Ammonia-N	27 mg/L Design
Effluent Water Parameters	
BOD (5 days)	16 mg/L
TKN (NH3-N)	10.87 mg/N
TSS	32 mg/L
Discharge Limits	
BOD (5 days)	30 mg/L (monthly average)
TKN	20 mg/L (monthly average)
TSS	30 mg/L (monthly average)
Other Information	
Four aerators (15 HP each) in each lagoon (replaced in Jan 2014) Duckweeds growing in the lagoon Sludge depth 6 ft and 4 ft Ammonia-Nitrogen violations in winter time	

AMMONIA NITROGEN DATA FROM LAGOON

Year	Average Ammonia-N concentration (mg/L)					
	Jan	Feb	March	April	May	June
2014	24	30	35	32	33	27
2015	29	32	24	22		
2016	22	20				

Duckweed growth indicates the presence of nutrients in the water. Uptakes carbon, nitrogen and phosphorus. Decay of dead duckweed releases these nutrients and BOD in the water.

Sludge depth greater than 2 ft results in:

1. Major reductions in hydraulic retention time and hence reduced treatment capacity;

2. Anoxic decomposition of the sludge layer results in generation of BOD and ammonia-nitrogen, which increases the need for additional dissolved oxygen; and

3. Incurs dredging costs, which are substantial and will cause large amounts of waste sludge to be dewatered and land filled.

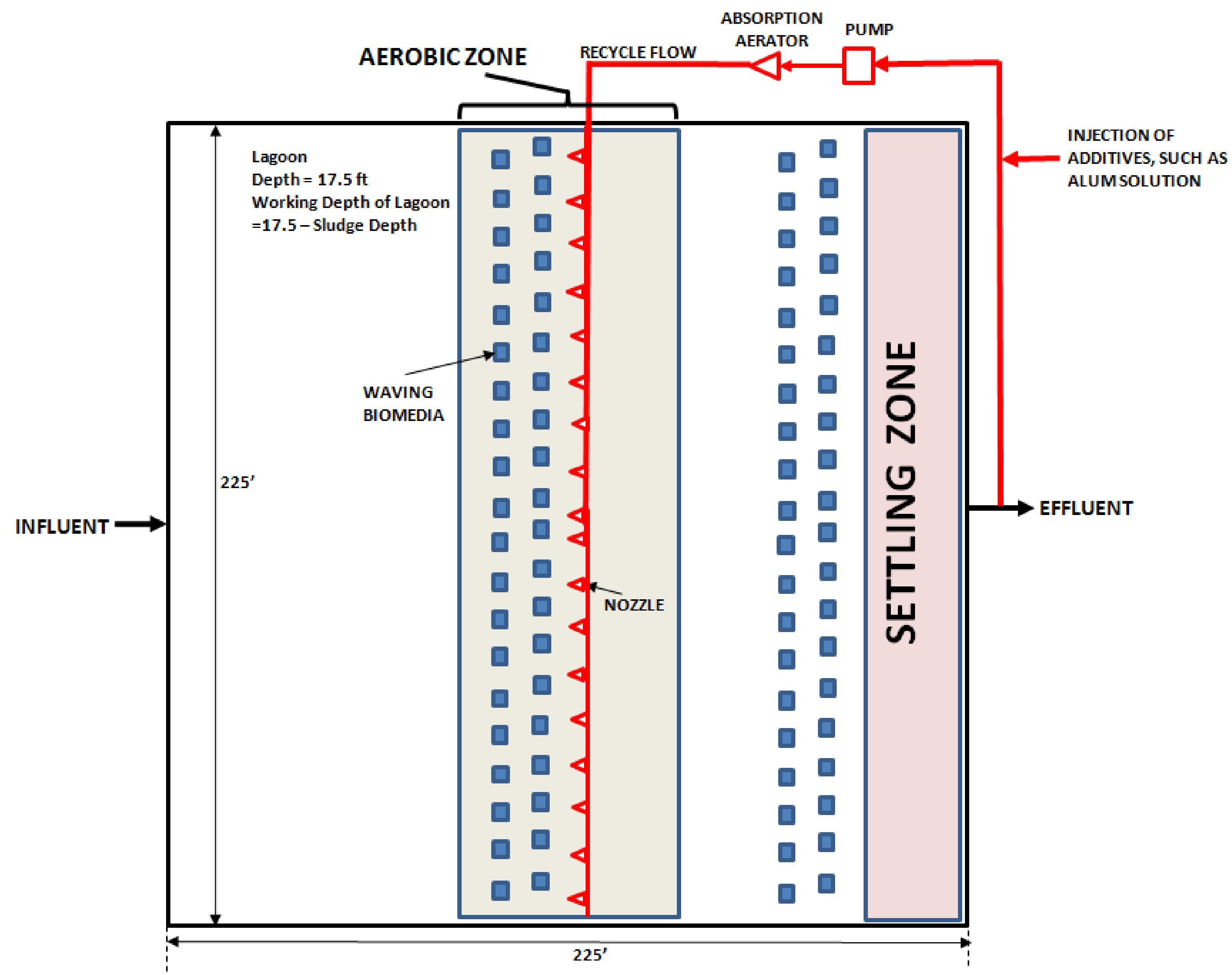
PROPOSED MODIFICATIONS

1. **MICROBUBBLE AERATION TO PROVIDE ADDITIONAL DISSOLVED OXYGEN (72 LBS/HR);**

2. **WAVING BIOMEDIA TO ENHANCE TREATMENT OF BOD AND NUTRIENTS (1200 PIECES, 17.5 FT HEIGHT);**

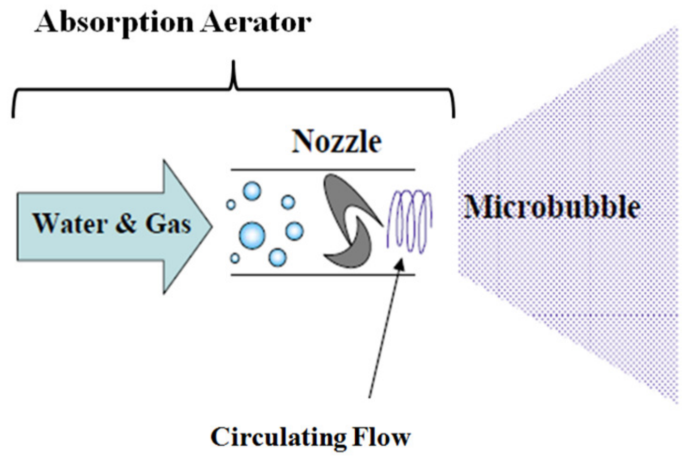
3. **ENZYME TOMAHAWKS TO REDUCE SLUDGE DEPTH (FIRST TWO YEARS)**

MICROBUBBLE AERATION



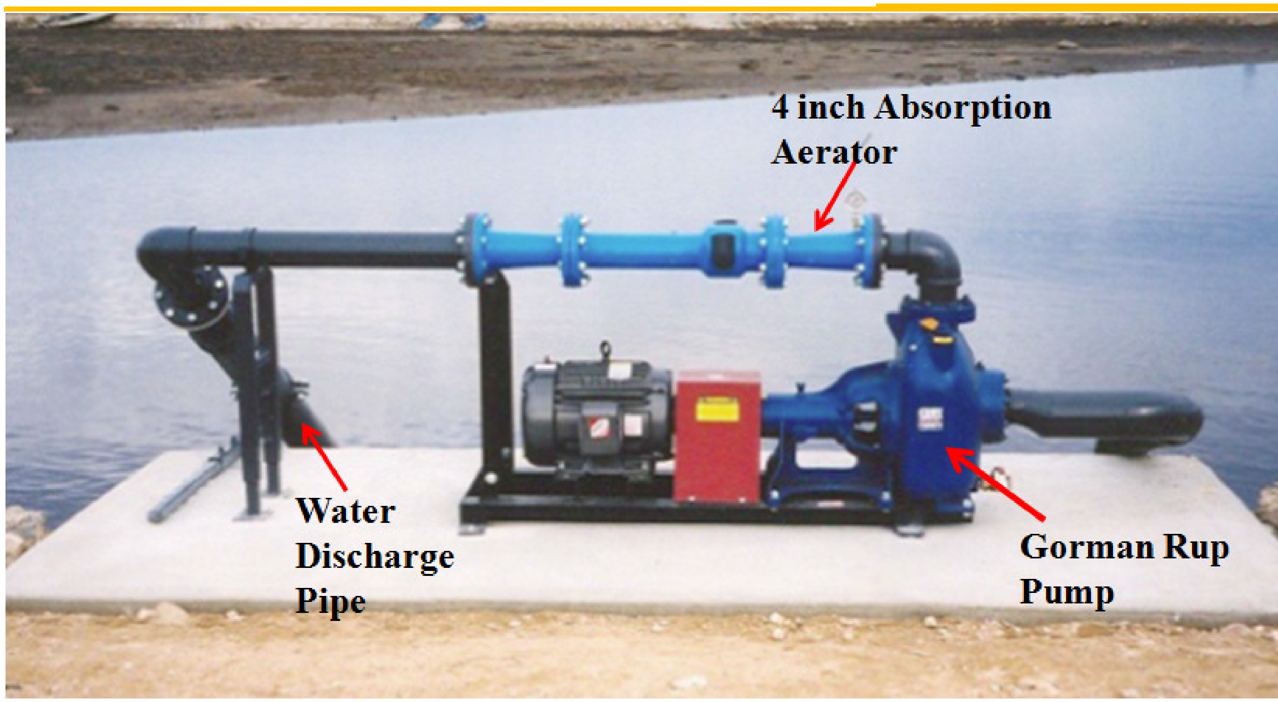
MICROBUBBLE AERATION

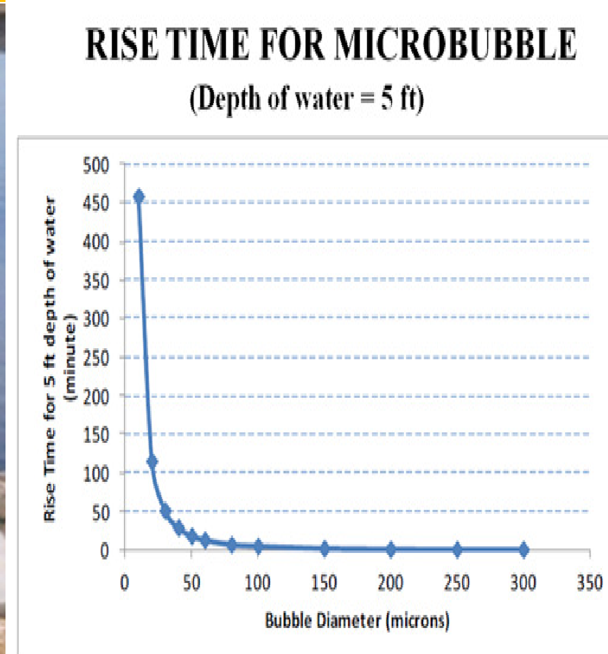
ABSORPTION AERATOR MECHANISM



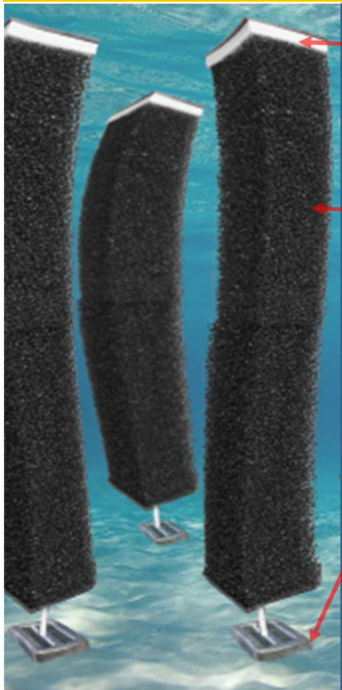
- Following are various AOTR's for mechanical aeration devices: lbs. O_2/hp/hr

Absorption Aerator	**2.73 -3.06**
Surface aerator w/draft tube	1.2 - 2.1
Surface high speed	1.2 - 2.0
Submerged turbine	1.0 - 2.0
Submerged turbine/sparger	1.2 - 1.8
Surface brush and blade	0.8 - 1.8
Fine Bubble Diffusers	0.5 - 1.5





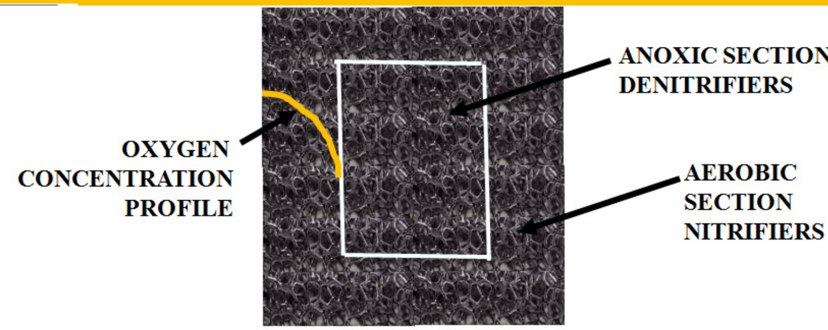
WAVING BIOMEDIA



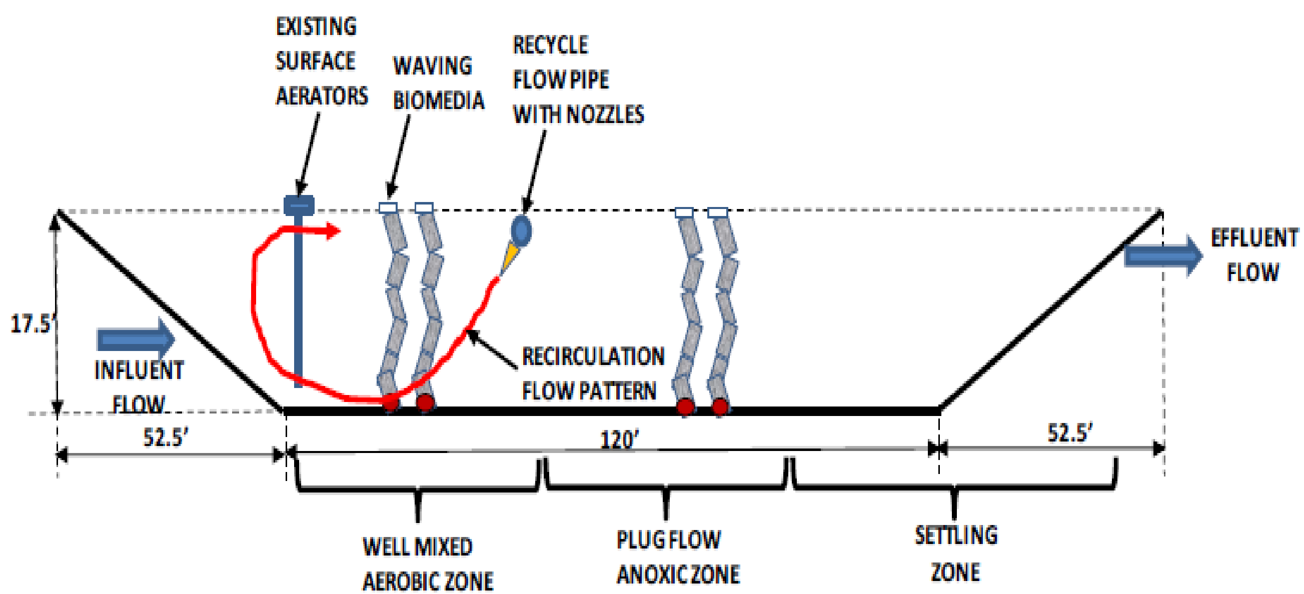
Flotation Foam to ensure that biomedia stays buoyant in the water, even after biofilm growth

Biomedia waves around in the water; High surface area, coated to allow rapid growth of active biofilms; treats BOD and denitrifies Nitrogen content in wastewater

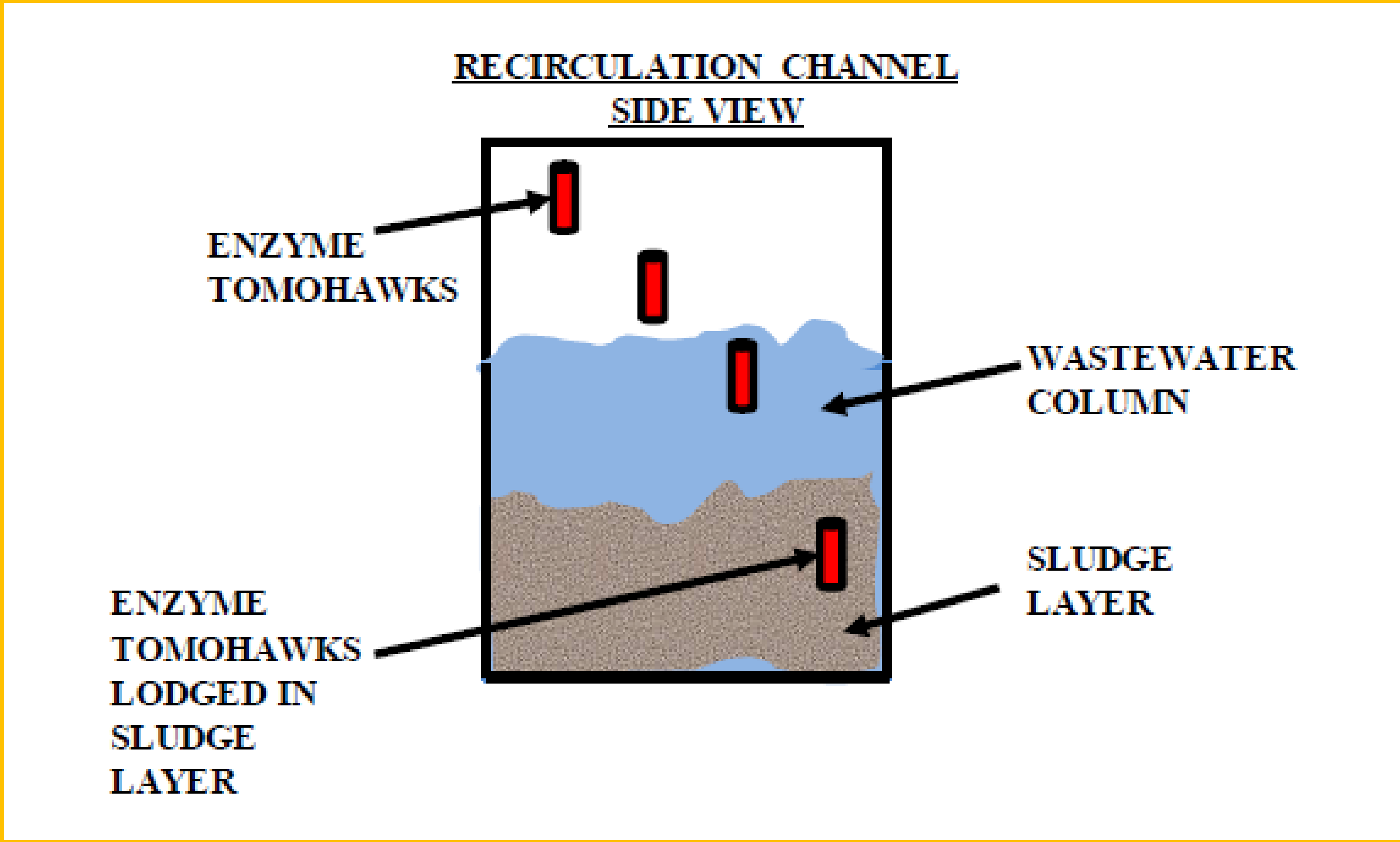
Weighted down to keep biomedia in place



- Waving Biomedia increases active biomass concentration from 200 – 500 mg/L in facultative lagoons and 1,200 – 2,000 mg/L in aerated lagoons, to 14,000 – 16,000 mg/L, thereby increasing biotransformation rates;
- Waving Biomedia retains nitrifiers and denitrifiers; and
- Increases sludge retention time (SRT), which allows biomass to decay and not accumulate in lagoon.



ENYME TOMAHAWKS



1. **Enzymes break up the sludge layer;**
2. **Allows dissolved oxygen penetration;**
3. **Disintegrates and Biodigestion of sludge**
4. **Reduces sludge depth over time**

COMPUTER SIMULATION

BRANDENBURG, KENTUCKY - GRW ENGINEERS

LAGOON SIMULATION

Name of Lagoon	Brandenburg	
Volume of Lagoon	6,626,813	Gallons
Area of Lagoon	50,625	ft2
Depth of water	17.50	feet
Height	18	feet
Influent Wastewater flowrate	312,000	gallons per day (gpd)
Influent temperature	70	deg F
Lowest Ambient Temperature	40	deg F
Highest Ambient Temperature	75	deg F
Number of cells in lagoon	1	
Type of Aeration system	1	Surface Aerators: 1; Submerged Bubble Aeration: 2 Absorption Aerator: 3
Influent Biological Oxygen Demand (BOD)	401	mg/L
Influent Total Suspended Solids (TSS)	371	mg/L
Influent Total Kjeideihl Nitrogen (TKN)	27	mg/L
Influent Ammonia (NH3)	27	mg/L
Influent Chemical Oxygen Demand (COD)	401	mg/L
Dissolved oxygen concentration in Lagoon	3	mg/L
pH of water in Lagoon	7.2	
Desired BOD Removal Efficiency in Lagoon	99	%
Desired TKN Removal Efficiency in Lagoon	98	%
Power from aerators in Basin	60	HP

COMPUTER SIMULATION

Kinetic Constants (assumed) (can be changed)

Kinetic Rate Constant for BOD at 20 deg C	1.6	day-1
Yield of Biological Solids by BOD degradation	0.67	
Temperature parameter for kinetic constant	1.06	
Biomass decay constant	0.07	day-1
Ratio of Volatile Suspended Solids to Total Biological Solids	0.8	
Conversion factor from BOD5 to BOD liquid	0.68	
Rating of surface aerators	3	lbs oxygen/hp.hr
Dissolved Oxygen concentration at 20 deg C	9.08	mg/L
Horse power required for complete mixing	0.6	hp/1000 ft3
Surface area of Waving Biomedia	200	ft2/ft3
Volume of each Wave Biomedia (4 in x 4 in x 17.5 ft)	1.94	ft3
Surface area of each Wave Biomedia	388.89	ft2
Maximum BOD Treatement Rate by Biomedia	0.005	lb BOD/ft2.day
Maximum TKN Treatment Rate by Biomedia	0.0004	lb TKN/ft2.day

COMPUTER SIMULATION

Design Calculations

Surface area of Lagoon	50,625	ft2
Lowest Lagoon Water temperature	50.2	deg F (If this is less than 32 deg F, there is possibility of
	10.1	deg C
Highest Lagoon Water temperature	73.3	deg F
	22.9	deg C
Hydraulic Retention Time	21.24	days
Kinetic constant for BOD in winter	0.8986	day-1
Kinetic constant for BOD in summer	1.8997	day-1
Exit BOD concentration in summer without Waving Biomedia	9.70	mg/L
Treatment Efficiency in summer with Waving Biomedia	97.58	% reduction in BOD
Exit BOD concentration in winter with Waving Biomedia	19.96	mg/L
Treatment Efficiency in winter with Waving Biomedia	95.02	% reduction in BOD
Concentration of Biological Solids Produced with Biomedia	105	mg/L VSS in summer
	103	mg/L VSS in winter
Suspended Solids in the Lagoon before settling with Biomedia	503	mg/L in summer
	499	mg/L in winter
Amount of biological solids produced that settle	274	lbs of sludge/day in summer
	267	lbs of sludge per day in winter
Effluent TKN Concentration with Waving Biomedia	16	mg/L
Effluent Ammonia concentration with Waving Biomedia	18	mg/L

Wastewater Engineering, Metcalf and Eddy, McGraw Hill, pages 608-611; 649-650

COST ANALYSIS

Budgetary cost for microbubble aeration, which consists of the external, self-priming pump, piping (6 in. PVC diameter) to carry the 1,100 gpm water recycle flow, nozzles and specially-designed venturi system, with PLC controls $167,200

Waving Biomedia, 17.5 ft height, 1,200 pieces at $100/piece $120,000

Total Budgetary cost, which does not include installation, shipping and commissioning $287,200

Yearly cost of Enzyme-Tomahawks, which will be needed for only two years .... $ 4,000/yr

Cost of Enzyme-Tomahawks in subsequent years will depend on the sludge layer thickness Reduction, as measured after 1 year of using the enzyme sticks.

COST ANALYSIS

Current yearly electrical cost of the eight (8) aerators	$63,000
Proposed yearly operating cost of the recycle pump (1100 gpm, 40 psi) Yearly electrical cost = =[(1100 gpm x 40 psi)/(1713 x 0.85)] x (1/1.341) kW/HP x 24 x 365 x $0.08 =	$15,800
Yearly cost of the existing four (4) aerators	$31,500
Yearly cost of the Enzyme Tomohawks for first year	$ 4,000
Total yearly electrical operating cost of proposed system	$51,300
Yearly saving in costs	$11,700

It may be more economical to install two (2) identical microbubble aeration systems with an additional yearly operating cost of $15,800 and shut down the existing four surface aerators, costing $31,500 per year. This will provide an additional yearly saving of $15,700 in electrical costs.

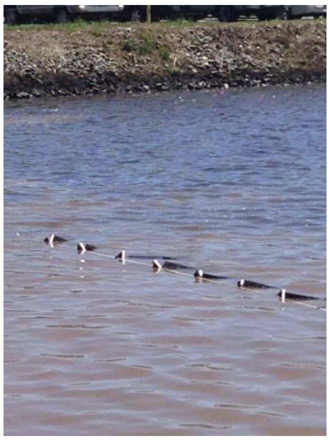
1. Improved performance in terms of reducing 5-day BOD and TKN in the effluent and meeting the required pollutant discharge limits; and

2. Reduction in sludge blanket over the two year time period, which will increase lagoon capacity substantially and reduce the generation of TKN in the effluent due to anaerobic decomposition of the sludge blanket; For example, in a 37 acre lagoon (depth of 12 ft) treating 12 MGD of wastewater, reduction of sludge blanket by 0.6 ft resulted in 41% increase in capacity, while the dredging cost was over $700,000, which did not include sludge dewatering and disposal.

ADDENDUM TO PROPOSAL
RESPONSES TO QUESTIONS

Question
Could you provide references for existing installations with waving biomedia? Could you provide photos of the installations and waving biomedia?

Response



Waving Biomedia has been installed in a lagoon that is treating wastewater from a chemical manufacturing facility. It has also been used in Advanced Septic Tanks that are currently treating sewage from homes, golf clubs and small businesses. The photograph shows the Waving Biomedia in the chemical manufacturing company's lagoon, in which the Waving Biomedia pieces were strung on a rope and then put into the water, so that they could be easily taken out, whenever the company needs to access the surface aerators, for repairs.

Question
The updated proposal notes that the existing 4 aerators will remain in service within the first lagoon. Will the existing aerators remain in their current locations? Or will they need to be relocated?

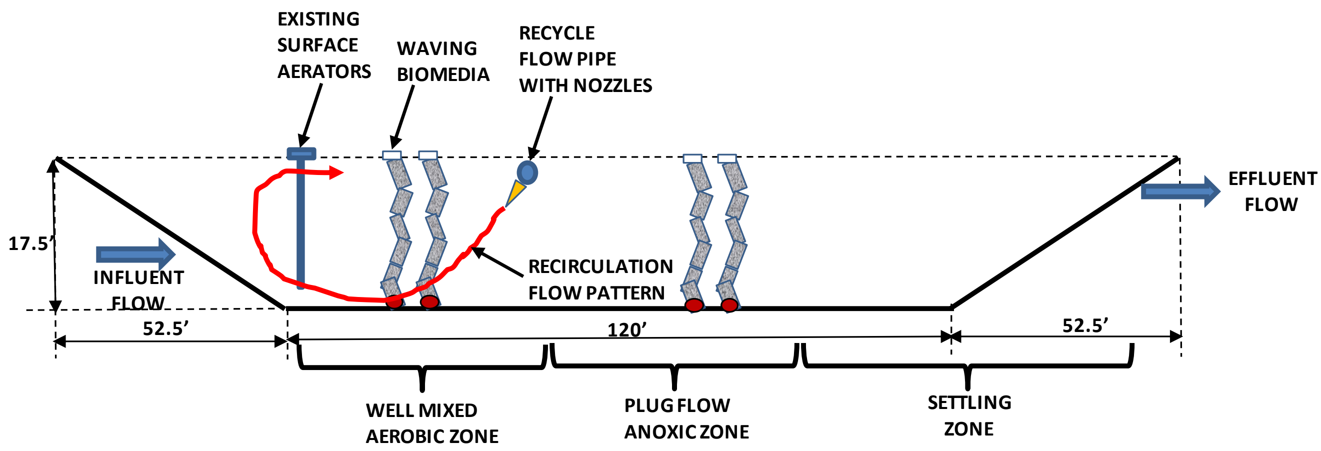
Response
Yes, the four aerators will be kept operating in the lagoon. They will be relocated within the lagoon with the four aerators in the entrance region of the lagoon, before the water enters the aerobic region of the lagoon, wherein the Waving Biomedia and microbubble aeration will be present.

Question
Would the 4 aerators within the second lagoon become backups since the second lagoon is no longer needed?

Response
Yes. The four aerators in the second lagoon will be used as backups in the event one or more of the aerators in the first lagoon fail.

Question
Are there any concerns with short circuiting? The existing influent and effluent into Lagoon 1 are located in the middle of the west and east side of the lagoon.

Response
Short-circuiting is always a major concern, especially in a lagoon wherein the length and width are equal. However, the microbubble aeration system will be injecting 1100 gpm of water and air into the lagoon, through several nozzles, and this injected flow will be in the reverse direction to the direction of water flow in the lagoon. Since the Microbubble aeration system will inject the water downwards, as shown below, it will set up a mixing pattern, taking water from the bottom and moving it to the top of the lagoon.



The lagoon will have three zones: (1) Well-mixed aerobic zone, near the lagoon entrance; (2) Anoxic plug flow zone; and (3) Settling zone, as shown in the figure.

Question
- Please provide cost justification for the operating cost of the existing aerators. Is this assuming 4 or 8 aerators in operation?

Response
Four aerators with 15 HP power consumption.
15 HP x 4 x (1/1.341) kW/HP x 24 hours/day x 365 days/year x $0.08/kW.hr = $31,350/year

Currently there are eight (8), 15 HP aerators operating, and hence the yearly electrical cost is $63,000.

Question
- Should the estimated operating cost for the proposed system include the operating cost of the existing 4 aerators? Please provide revised operating cost and justification.

Response
Current yearly electrical cost of the eight (8) aerators $63,000

Proposed yearly operating cost of the recycle pump (1100 gpm, 40 psi)
Yearly electrical cost =
=[(1100 gpm x 40 psi)/(1713 x 0.85)] x (1/1.341) kW/HP x 24 x 365 x $0.08 = $15,800

Yearly cost of the existing four (4) aerators $31,500

Yearly cost of the Enzyme Tomohawks for first year	$ 4,000
Total yearly electrical operating cost of proposed system	$51,300
Yearly saving in costs	$11,700

It may be more economical to install two (2) identical microbubble aeration systems with an additional yearly operating cost of $15,800 and shut down the existing four surface aerators, costing $31,500 per year. This will provide an additional yearly saving of $15,700 in electrical costs.

There are other significant benefits that have not been monetized. These benefits are as follows:

1. Improved performance in terms of reducing 5-day BOD and TKN in the effluent and meeting the required pollutant discharge limits; and

2. Reduction in sludge blanket over the two year time period, which will increase lagoon capacity substantially and reduce the generation of TKN in the effluent due to anaerobic decomposition of the sludge blanket; For example, in a 37 acre lagoon (depth of 12 ft) treating 12 MGD of wastewater, reduction of sludge blanket by 0.6 ft resulted in 41% increase in capacity, while the dredging cost was over $700,000, which did not include sludge dewatering and disposal.

Question

The schematic of the proposed system shows the settling zone after the two zones of waving biomedia. Is the location of the settling zone on the schematic based on being located after the waving biomedia? Does settling occur in any other location within the lagoon? What is the size of the settling zone? Based on the schematic, the settling zone would be located on the side slopes of the lagoon. With the 3:1 side slopes on all sides, there is only a 120’-0” x 120’-0” flat area in the middle of the lagoon. Due to the 3:1 side slopes, would the sludge be able to accumulate as shown?

Response

The schematic was not a scale drawing and was only intended to show the various operating regimes within the lagoon. The three zones within the lagoon, as shown before and shown again below are as follows: (1) Well-mixed, aerobic zone near the lagoon entrance; (1) Plug-flow, Anoxic zone; and (3) Settling zone.

The well-mixed, Aerobic zone with 6 rows of Waving Biomedia is about 30 ft in length, followed by the plug-flow, anoxic zone, which is also about 30 ft in length, and the Settling zone which will be 60 ft length, as measured at the bottom of the lagoon (total length at bottom is 120 ft). The Settling zone of 60 ft will have the sloping side as an additional settling area.

The sludge settling on the sloping sides will slide down the slope and accumulate at the bottom flat portion of the lagoon.

Question

· Without the using enzyme-tomahawks, what is the anticipated sludge accumulation rate? What volume of sludge would cause the system to no longer meet permit limits? If the enzyme-tomahawks are not able to keep up with the sludge accumulation and the sludge needs to be removed by an alternative method, could the lagoon be dredged and remain in operation?

Response

The sludge production rate can be calculated using the equations for the lagoon, that have been implemented as an Excel computer program. The results of this calculation are shown below:

The input parameters are as follows:

LAGOON SIMULATION		
Name of Lagoon	**Brandenburg**	
Volume of Lagoon	6,626,813	**Gallons**
Area of Lagoon	50,625	**ft2**
Depth of water	17.50	**feet**
Height	18	**feet**
Influent Wastewater flowrate	312,000	**gallons per day (gpd)**
Influent temperature	70	**deg F**
Lowest Ambient Temperature	40	**deg F**
Highest Ambient Temperature	75	**deg F**
Number of cells in lagoon	1	
Type of Aeration system	1	**Surface Aerators: 1;** **Submerged Bubble Aeration: 2** **Absorption Aerator: 3**
Influent Biological Oxygen Demand (BOD)	401	**mg/L**
Influent Total Suspended Solids (TSS)	371	**mg/L**
Influent Total Kjeideihl Nitrogen (TKN)	27	**mg/L**
Influent Ammonia (NH3)	27	**mg/L**
Influent Chemical Oxygen Demand (COD)	401	**mg/L**
Dissolved oxygen concentration in Lagoon	3	**mg/L**
pH of water in Lagoon	7.2	

The results of the calculation are shown below:

Design Calculations		
Surface area of Lagoon	50,625	**ft2**
Lowest Lagoon Water temperature	50.2	**deg F (If this is less than 32 deg F, there is possibility of**
	10.1	**deg C**
Highest Lagoon Water temperature	73.3	**deg F**
	22.9	**deg C**
Hydraulic Retention Time	21.24	**days**
Kinetic constant for BOD in winter	0.8986	**day-1**
Kinetic constant for BOD in summer	1.8997	**day-1**
Exit BOD concentration in summer without Waving Biomedia	9.70	**mg/L**
Treatment Efficiency in summer without Waving Biomedia	97.58	**% reduction in BOD**
Exit BOD concentration in winter without Waving Biomedia	19.96	**mg/L**
Treatment Efficiency in winter without Waving Biomedia	95.02	**% reduction in BOD**
Concentration of Biological Solids Produced without Biomedia	105	**mg/L VSS in summer**
	103	**mg/L VSS in winter**
Suspended Solids in the Lagoon before settling without Biomedia	503	**mg/L in summer**
	499	**mg/L in winter**
Amount of biological solids produced that settle	274	**lbs of sludge/day in summer**
	267	**lbs of sludge per day in winter**

So the amount of biological solids produced that will settle are 274 lbs/day in summer and 267 lbs per day in winter. The production rate changes with temperature, since the kinetic constant varies with temperature.

Use of Enzyme Tomahawks will accelerate the breakdown of the sludge, as long as there is enough dissolved oxygen in the water to aerobically digest this sludge.

However, if the Enzyme Tomahawks are unable to keep up with sludge production, then the lagoon would have to be dredged, which can be done in the settling region of the lagoon.

Question

What is the expected effluent concentrations for BOD, TSS, and NH_3? What are the differences in effluent concentrations during the summer and winter months? Can you provide calculations supporting your expected effluent concentrations? Or, are the effluent concentrations based solely on a model? If so, could you provide information on the model?

Response

In the above calculation, the reduction of BOD is 95% with an influent BOD of 401 mg/L, i.e., 20 mg/L. The TKN concentration in the effluent is calculated to be 8 mg/L. The model has been discussed in detail in *Wastewater Engineering – Treatment, Disposal and Reuse*, Metcalf and Eddy, McGraw Hill, Third Edition, 1991. I am sure there is a later edition of this book also.

The TSS calculation uses a settling rate in the settling section of the lagoon. I used a settling rate of 3.6 ft/h, which is typical for settling of sludge. This value is also used in the above reference.

Question

The updated proposal eliminates the need for the second lagoon. Do you have any recommendations for potential uses of the second lagoon? We are just brainstorming for potential ways to purpose the lagoons, if feasible.

Response

The second lagoon can be repurposed as a settling lagoon, so it can be used in series after the first lagoon, after the settling zone of the first lagoon. This will provide more settling area for the solids, and since the solids will be settling over a larger area, the sludge depth will be less. Of course in this case, the flow velocity in the lagoon can be higher, i.e., the two lagoons, with the first lagoon for treating the water and the second lagoon for settling the biomass, will be able to handle a significantly higher flowrate of water.

Question

- Are there any O&M costs in addition to the electrical requirements of the aerators and enzyme-tomahawks? Does the waving biomedia require any maintenance? What is the life expectancy of the waving biomedia?

Response

The only other O& M cost can be Alum solution, in case, the settling rate is slower than expected. Alum solution can be injected into the recycle flow of the wastewater, and this will accelerate the settling rate of the biomass. Also, if the pH of the wastewater needs adjustment, acid/base can be injected in the recycle water to modify the pH to near neutral value.

The Waving Biomedia will last more than 10 years and although we warranty this biomedia for 10 years, typically, there is no degradation mechanism for the foam material, and hence it should last for more than 10 years.

Question

- Would lagoon 1 be considered a completed mix lagoon?

Response

AS shown in the figure, the aerobic section of lagoon 1 can be considered a completely mix lagoon. However, it has a plug-flow anoxic section, following the aerobic section, as shown in the figure, given earlier in this document

LemTec™ Process

LEMNA TECHNOLOGIES, INC.

Municipal and Industrial Treatment

Innovative Wastewater Solutions

The Leader In Lagoon Process Technology

The LemTec™ Biological Treatment Process (LBTP) treats wastewater as it flows through a series of aerated lagoons that are divided by baffles to reduce short-circuiting. In colder climates, each cell is covered by a LemTec™ Modular Cover, which enhances system kinetics, retains heat, controls odors, and prevents algae growth. In warmer climates, it may be necessary to cover only the final settling cell in order to promote digestion of sludge and prevent algae growth. Additional technologies, including the Lemna Polishing Reactor and the Lemna Phosphorus Removal System, may also be used for enhanced nutrient removal.

Customer satisfaction is our highest priority . . .

"The installation went very well, and the performance of the system has been excellent. We have been within our discharge limits since the installation, and have been more than satisfied with the performance of this system. I would most certainly recommend the Lemna system to other municipalities which use oxidation ponds and find themselves having problems with discharge limits." ***Operator - R.D., Louisiana***

"Lemna is definitely a leader rather than a follower. In addition, the LemTec™ Biological Treatment Process has over the last two years proven to be an excellent choice. The installation process is simple yet effective in its high degree performance and low maintenance cost." ***Client - B.L., New Hampshire***

"It has been a pleasure to work with Lemna Technologies. The service and support is fast and friendly." ***Client - P.V., Wisconsin***

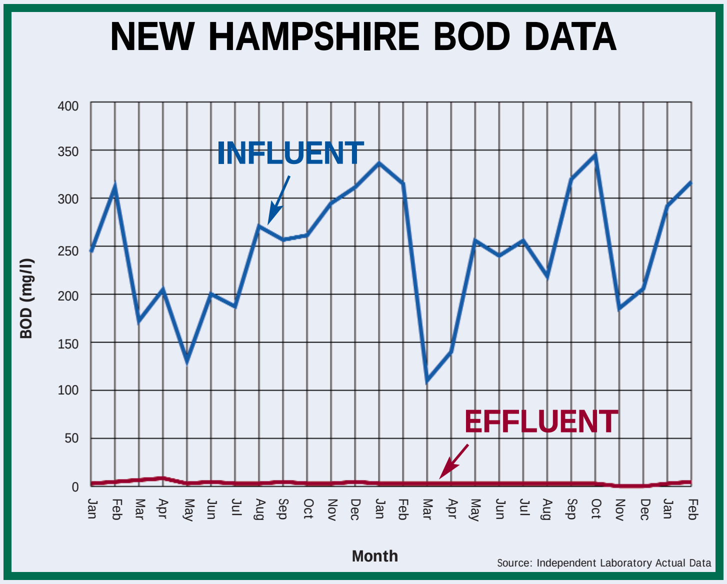
LemTec™ Process Family

LemTec™ Biological Treatment Process is an effective, reliable and affordable solution for existing aerated municipal and industrial wastewater lagoon facilities. The system incorporates the LemTec™ Modular Cover to create a reduced footprint and an operation that is virtually odor-free. The LemTec™ system is the highest performing pond-based aerated lagoon process in the world. Utilizing a series of aerobic treatment cells followed by an anaerobic settling zone and polishing reactor, the LemTec™ Process is capable of achieving year-round effluent limits as low as 10 mg/l BOD, 15 mg/l TSS and 2 mg/l NH_3-N for typical municipal or pre-treated industrial wastewater. Other nutrients such as Phosphorus can also be addressed within the process.

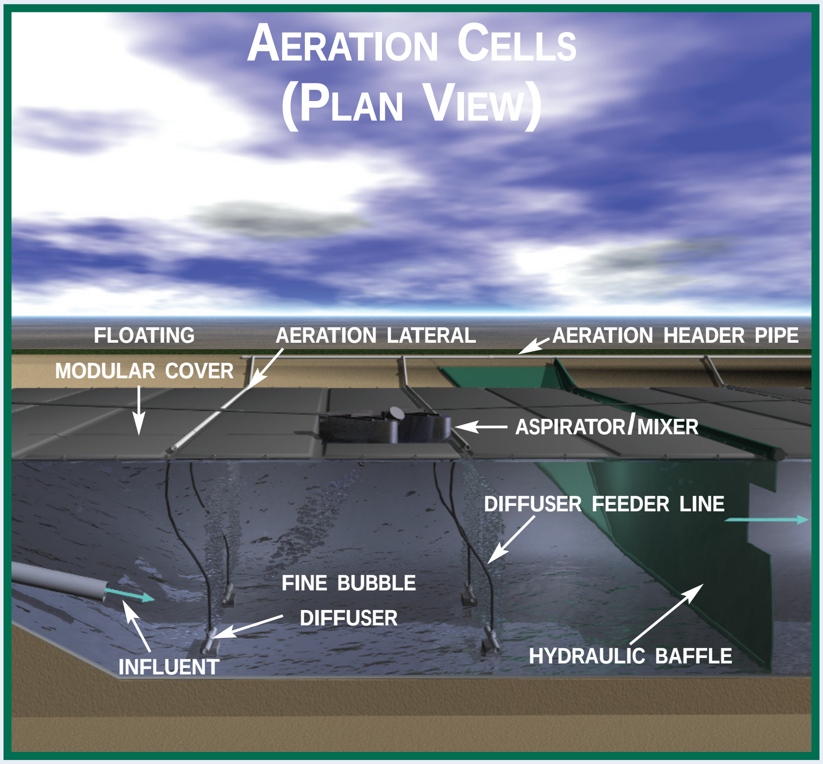
Existing Lagoons or New Construction

LemTec™ Facultative Treatment Process is an effective, reliable and affordable solution for existing facultative municipal and industrial wastewater lagoon facilities. At a fraction of the cost of other traditional systems, the LemTec™ Facultative Treatment Process is unmatched in its ability to meet stringent effluent limits that other traditional pond-based systems can't reach. Utilizing a series of facultative treatment cells followed by a covered settling zone and Lemna Polishing Reactor, the LemTec™ Process is capable of achieving year-round effluent limits as low as 10 mg/l BOD, 15 mg/l TSS and 2 mg/l NH_3-N.

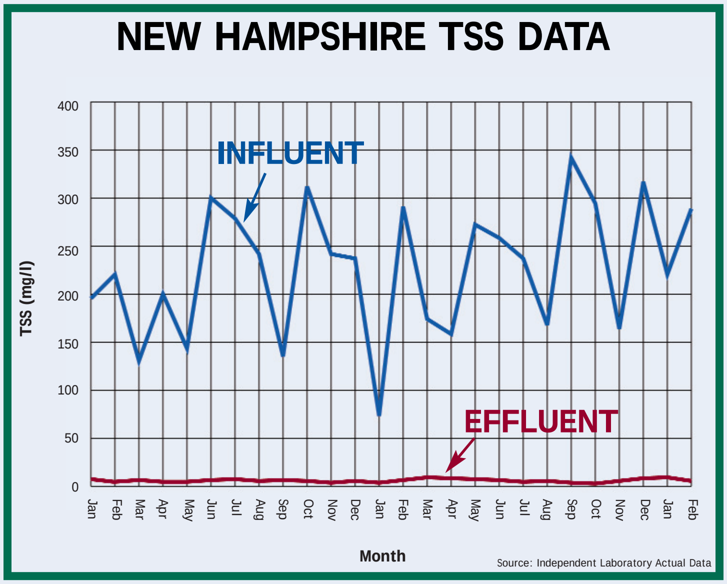
BOD Removal



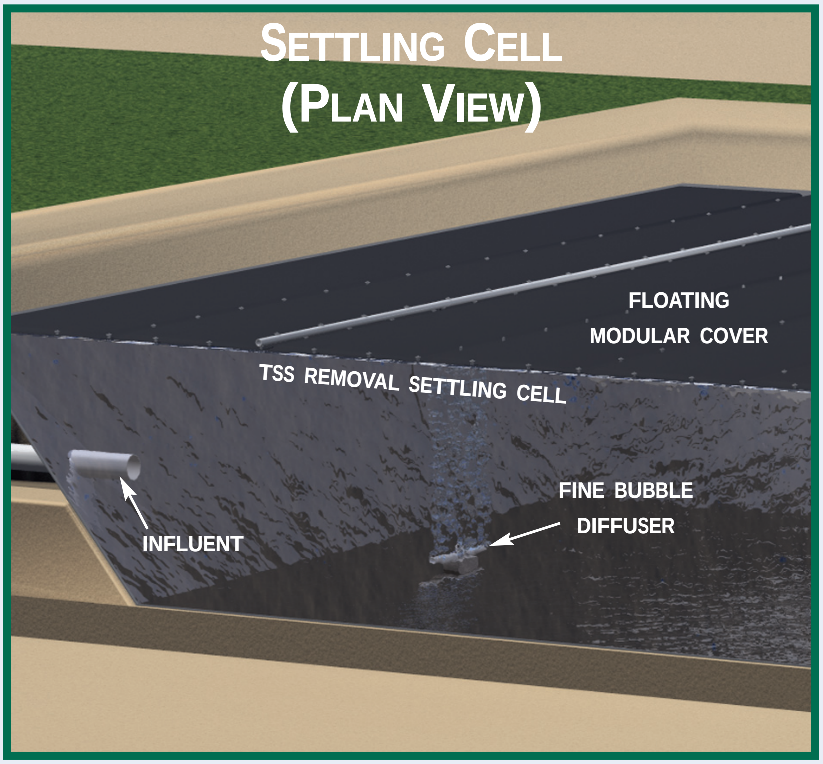
Achieving BOD levels below 10 mg/l reliably and consistently throughout the year. BOD removal to below 30 mg/l is accomplished in the complete mix and partial mix cells of the treatment process with final polishing to below 10 mg/l in the Lemna Polishing Reactor, if required. Lemna's design minimizes temperature fluctuations and the adverse treatment effects of peak flow events on BOD removal. Our low horsepower design is efficient in both aeration and mixing and requires a smaller footprint that is typically 12 days or less in detention time.



TSS Removal



Lemna's settling cell - a clarifier without the moving parts. The settling pond, covered with the LemTec™ Modular Cover, creates an effective zone for clarification of biosolids. The cover prevents algae growth by eliminating sunlight and improves clarification in two ways: 1) it prevents wind action on the water surface, thereby establishing a quiescent zone for solids to settle; and 2) the insulation minimizes seasonal and diurnal temperature fluctuation thereby reducing stirring by thermal currents. In addition, the anaerobic environment in the settling pond digests the biosolids significantly over time with no sludge disposal required for at least 5 to 7 years.

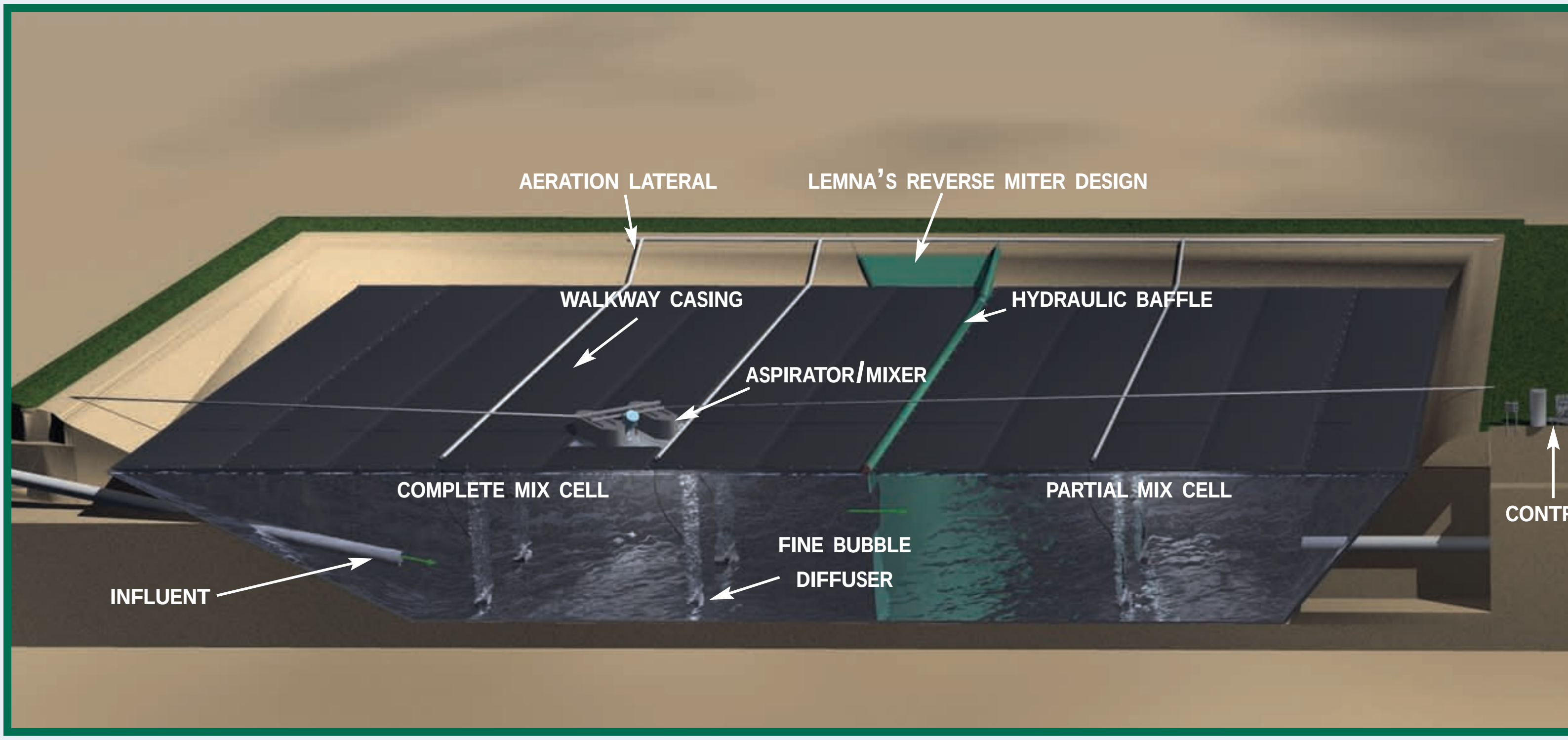


THE LEMTEC™ BIOLOGIC

"We have done numerous projects over the last five years using Lemna Technologies Inc., and I highly recommend this company. They are very proficient, have excellent take-offs, detailed instructions, the product is easy to install and their supervisors are knowledgeable and skilled. We look forward to the next opportunity to work with them." ***Contractor - T.S., Louisiana***

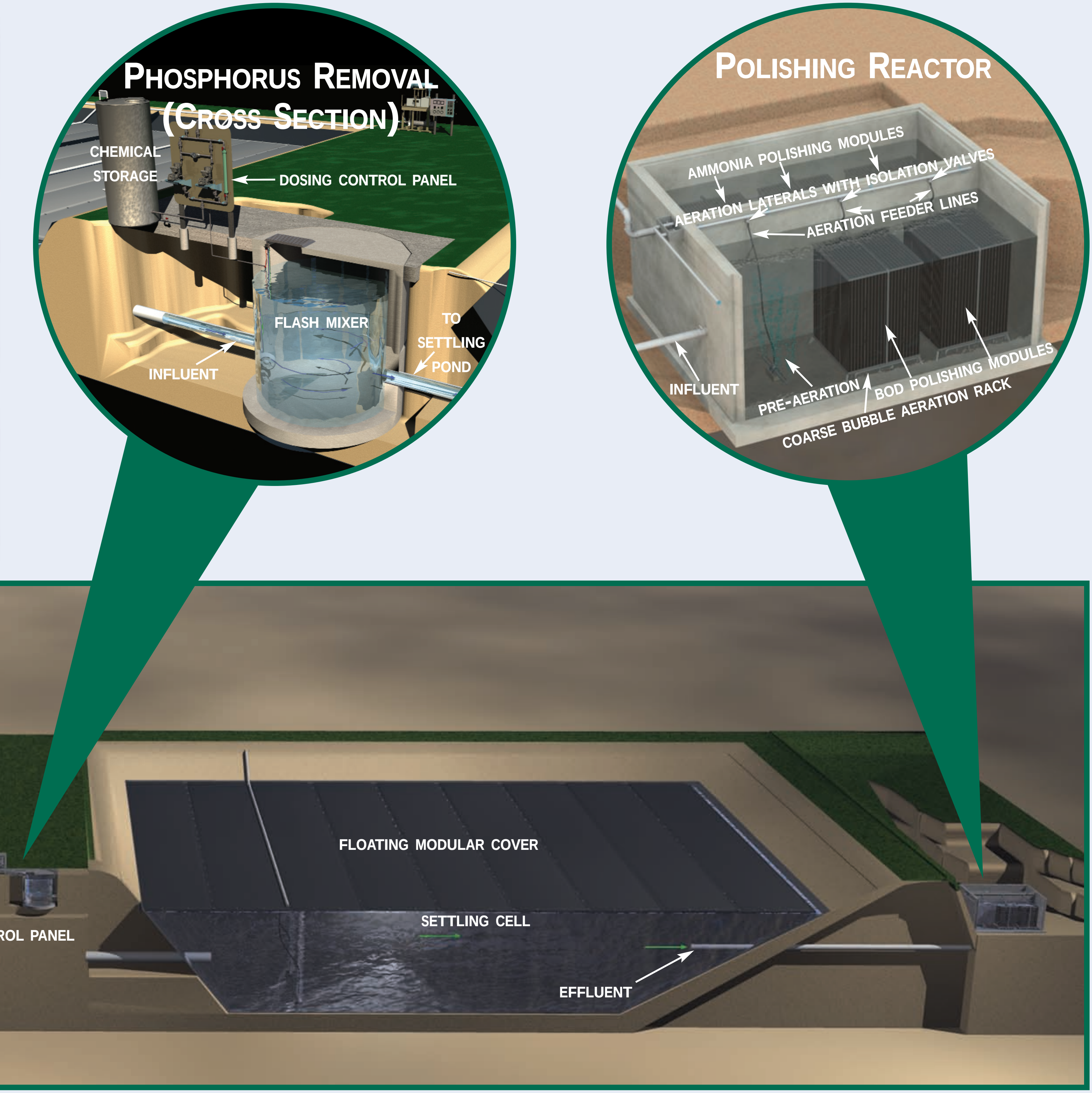
"Since installation, we have noticed excellent odor control, algae control, and our effluent test levels are remarkable. To encourage the choice of Lemna Technologies products, we welcome anyone interested to tour our facilities and/or review our weekly test results." ***Client - J.R., Iowa***

Lemna's cover and staff have provided performance as promised. Anytime we've had questions related to technical support, Lemna has been prompt in their response. I can safely state that maintenance on our cover has been virtually non-existent, and I highly recommend Lemna for anyone considering them for a cover or liner." ***Client - R.L., Minnesota***



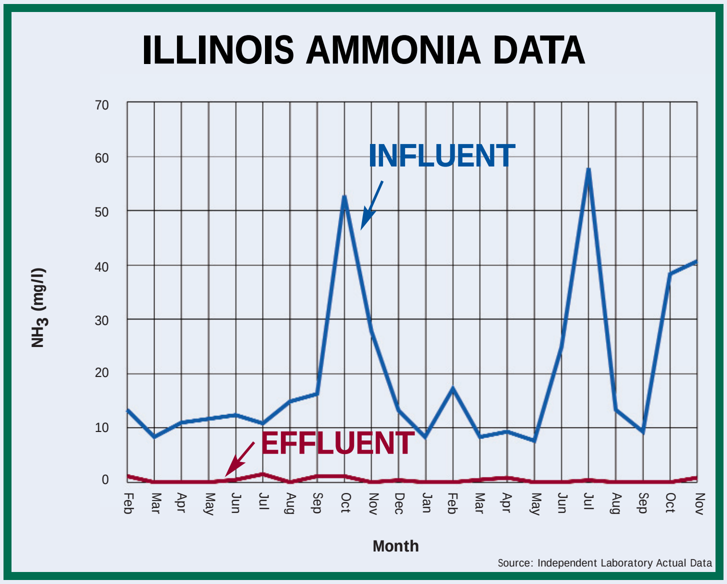
CUSTOM-DESIGNED TO ME

CAL TREATMENT PROCESS

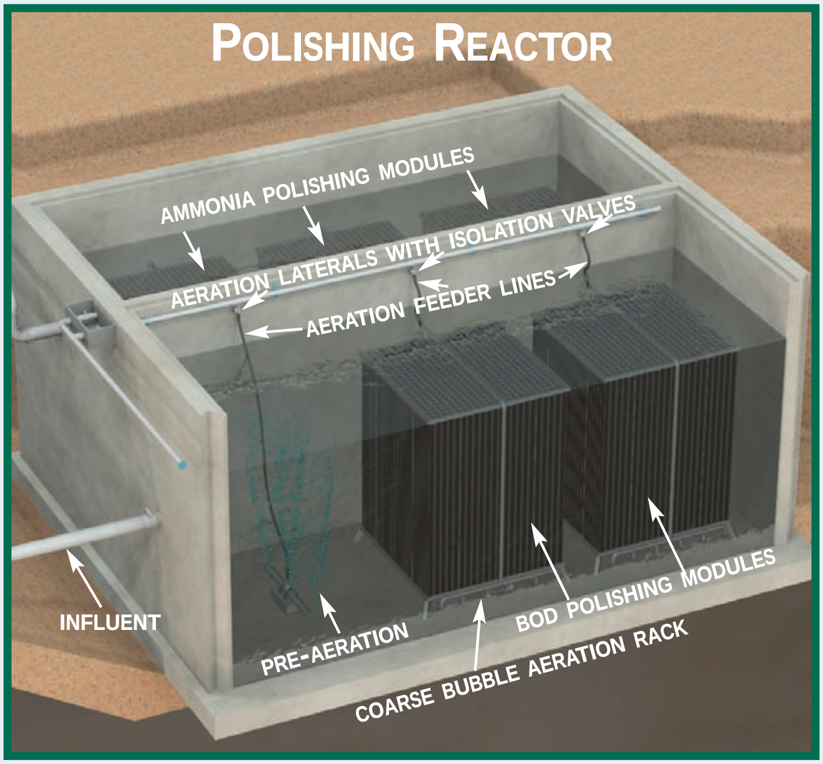


ET YOUR SPECIFIC NEEDS!

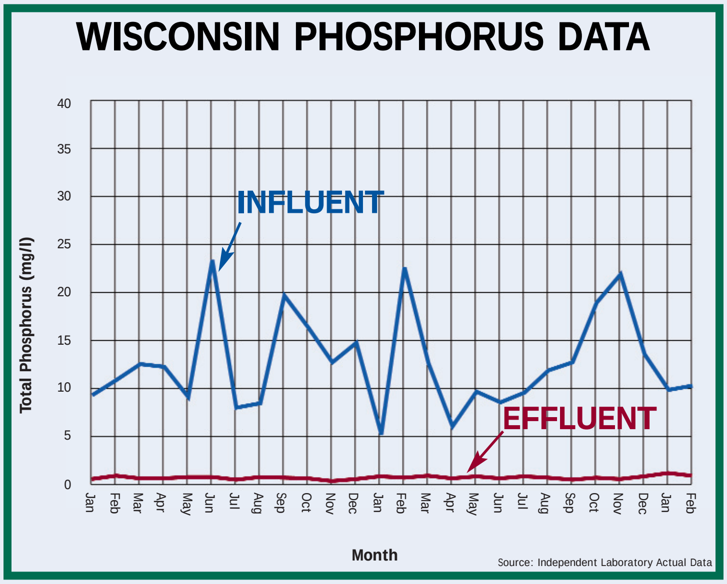
Ammonia Removal



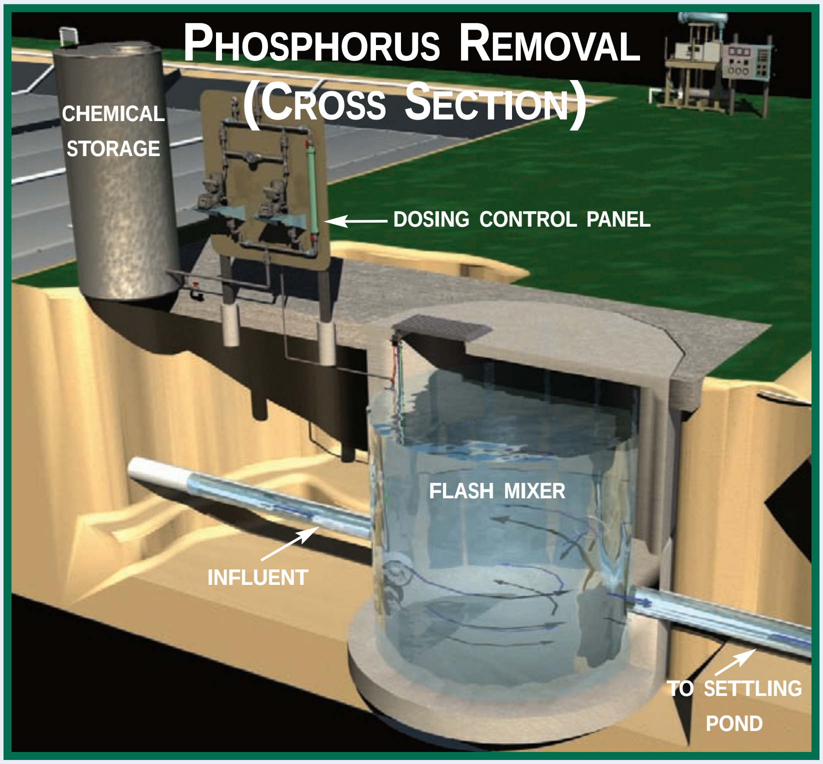
The Lemna Polishing Reactor (LPR) reduces Ammonia Nitrogen (NH_3-N) and BOD. The majority of both BOD and Ammonia removal in the Lemna design occurs in the complete mix cell. However, the LPR is included in the LBTP design to meet low BOD_5 (<10 mg/l) and NH_3 (<1 mg/l) limits if required. The LPR utilizes fixed media to promote an environment for submerged attached-growth bacteria. The LPR is composed of stainless steel hardware and frames that compress UV resistant PVC media, making the reactor sturdy and one of the best filters in the industry.



Phosphorus Removal



We use a chemical dosing system, low horsepower pumps and mixers that make operation easy. Phosphorus is precipitated chemically by the addition of coagulants, including alum or ferric chloride. Precipitation causes contaminants that are either dissolved or suspended to settle out of solution as solid floc particles that are removed along with waste biological sludge. Our system is low cost and reliable.

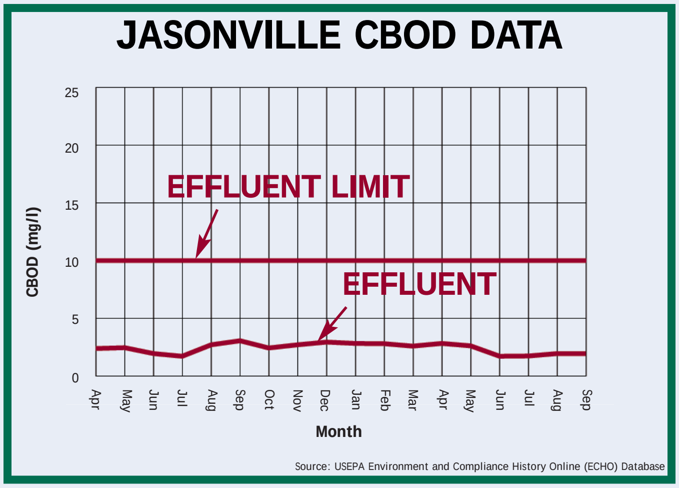


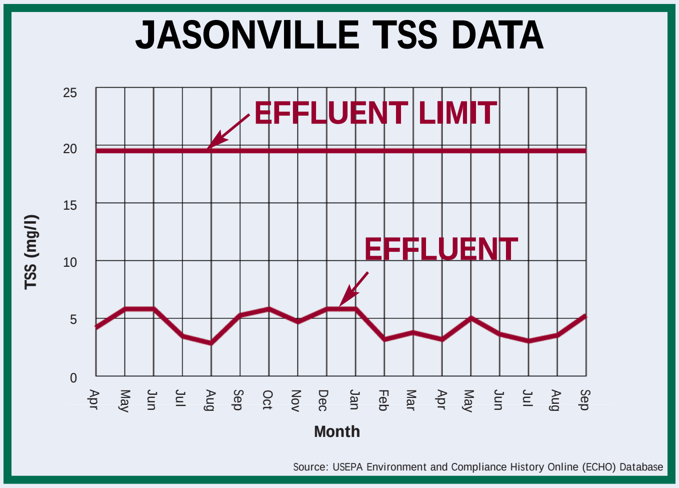
Case History

Aerated lagoon upgrades

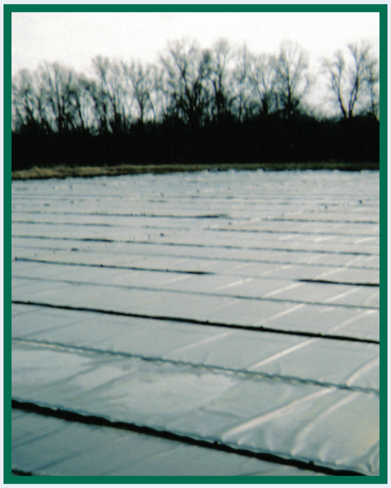
Case Study: Jasonville, Indiana

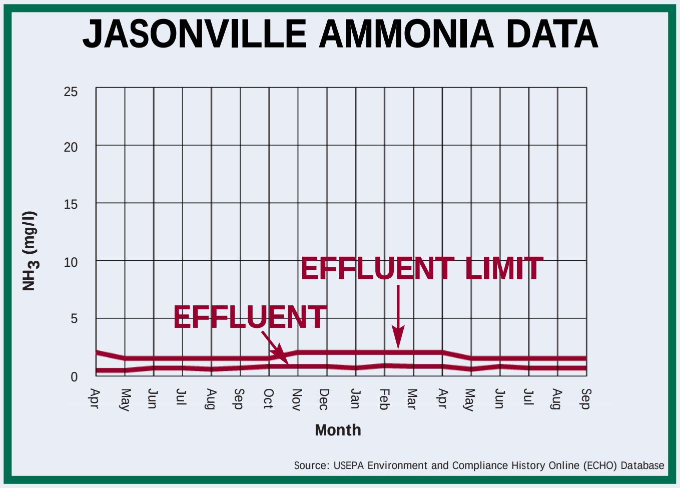
Project Background: The wastewater treatment plant, located in Jasonville, Indiana, was an existing lagoon system that no longer performed to the new environmental regulations for Ammonia. The Ammonia removal process, which is difficult in any wastewater treatment system, is especially complex in cold weather climates like Jasonville.





This system was designed to incorporate the existing lagoons and aeration equipment to create the most cost effective system. There were two existing large wastewater treatment ponds. The entire first pond was incorporated into this design and half of the second pond was used by constructing a berm in that pond. The aeration pond has a detention time of 15.8 days. The aeration cell is partially mixed. New diffused aeration was added to supplement the existing aeration. The third cell is a settling cell with a detention time of 7.4 days. The settling pond is followed by a Lemna Polishing Reactor (LPR) consisting of sixteen media modules for effluent polishing.





Site Performance: The Jasonville facility provides reliable removal of CBOD, TSS and Ammonia over a wide range of operating conditions including high flows, cold operating temperatures and variable loads.

FEATURES AND BENEFITS

Easy to Operate

- Minimal operator requirements
- No complicated sludge handling
- No solids return/recycle
- Start-up and operator training provided

Flexible Designs

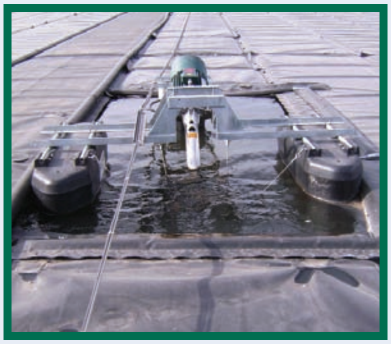
- New or existing lagoons
- Reliable at high or low flows
- Easy to expand for future flows
- Designs for any climate

Affordable

- Small footprint and land required
- Minimal HP required
- Low operator costs
- Simple construction

Proven Technology

- 25 years of experience
- The leader in lagoon nitrification
- Dedicated to the environment

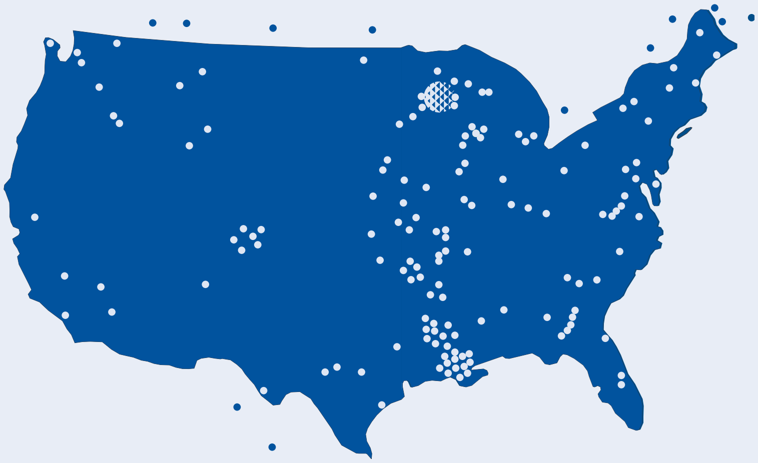


"The city purchased a turn-key wastewater treatment facility over 20 years ago. I would recommend Lemna to any community or industry in need of water treatment." ***Client - J.M., North Dakota***

Wastewater Treatment Experts

Lemna has been the world leader for more than 25 years in high-performance lagoon-based wastewater treatment technologies. We have 100's of treatment facilities with installations on four continents.

Headquartered in Minneapolis, Minnesota, Lemna designs and installs systems for all municipal and industrial applications. Lemna provides a full range of wastewater design and engineering services, backed by exceptional results and customer service.



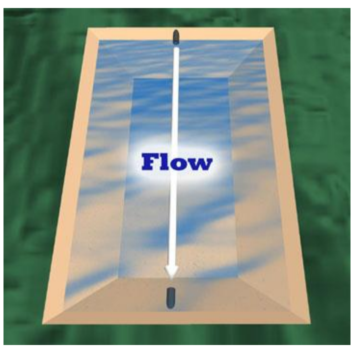
"LEMNA PROVIDES A SIMPLE SOLUTION FOR WASTEWATER TREATMENT PROBLEMS"

Lemna Technologies, Inc.
2445 Park Avenue
Minneapolis, Minnesota, U.S.A. 55404-3790
Phone: (612) 253-2002
Fax: (612) 253-2003
e-mail: techsales@lemna.com
www.lemnatechnologies.com

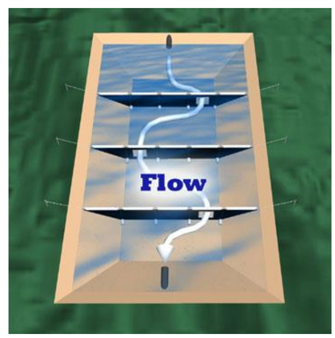
Hydraulic Baffle

System Overview

The WWTP includes a floating baffle to improve the flow performance in the lagoon by eliminating short-circuiting, stagnant zones, and premature settling. Floating baffles offer the benefit of producing efficient flow patterns in lagoons for the most effective waste treatment!

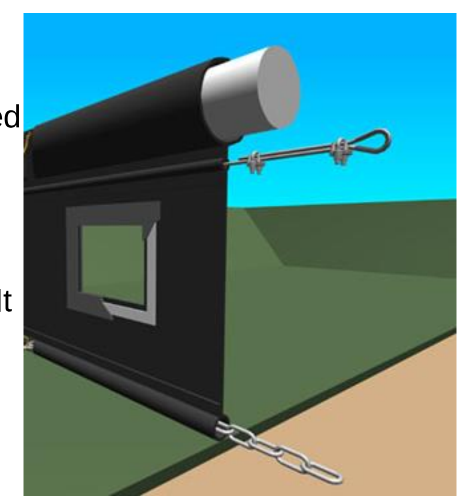


Before

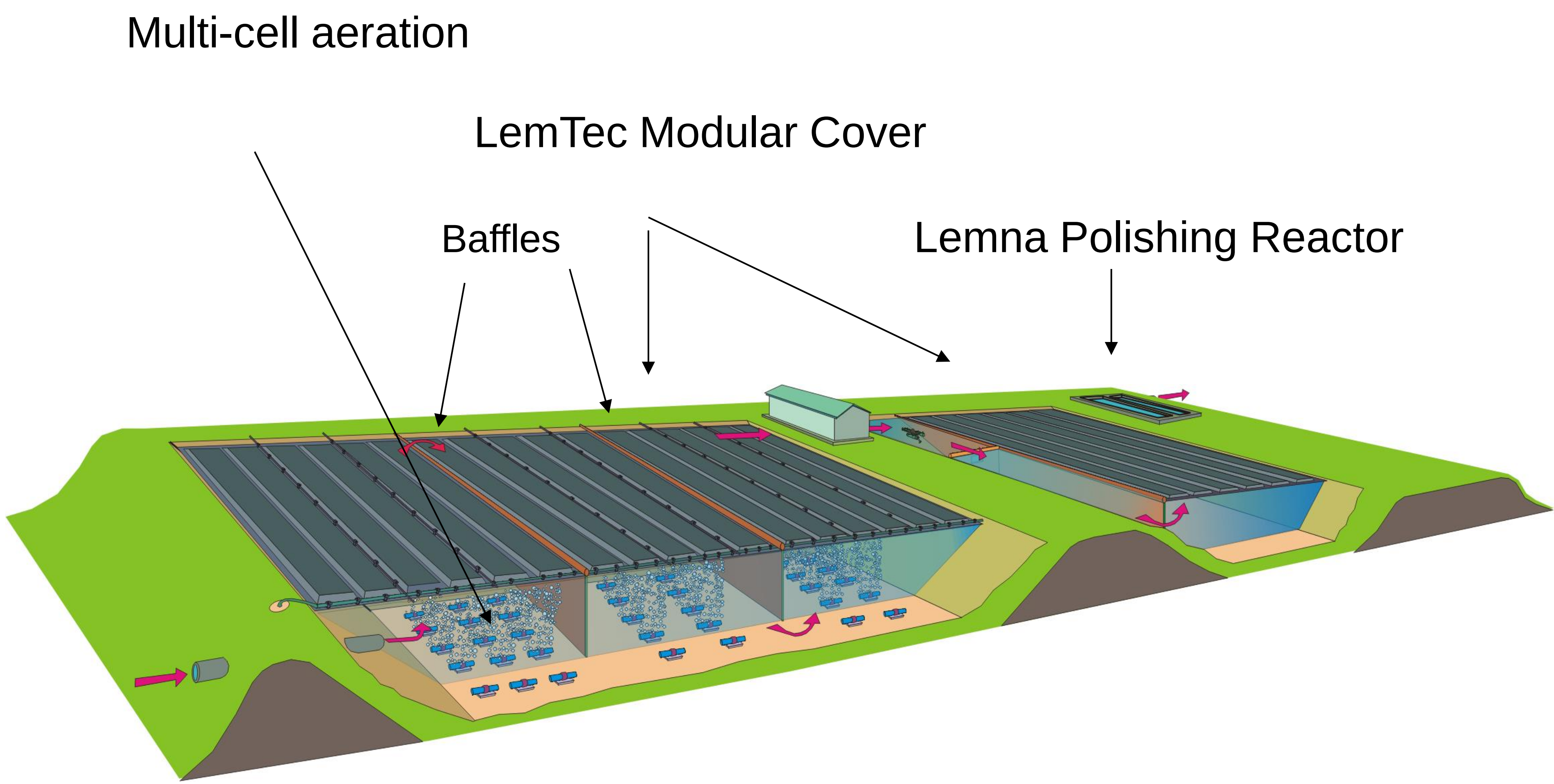


After

Each baffle is custom designed for the specific application. The baffle is factory fabricated incorporating all structural components. Developed specifically for wastewater treatment, this progressive design eliminates spare parts inventories and speeds the installation process. The Lemna Baffle arrives at the site ready for installation in either a filled or dewatered lagoon. It can also be removed without dewatering the lagoon.

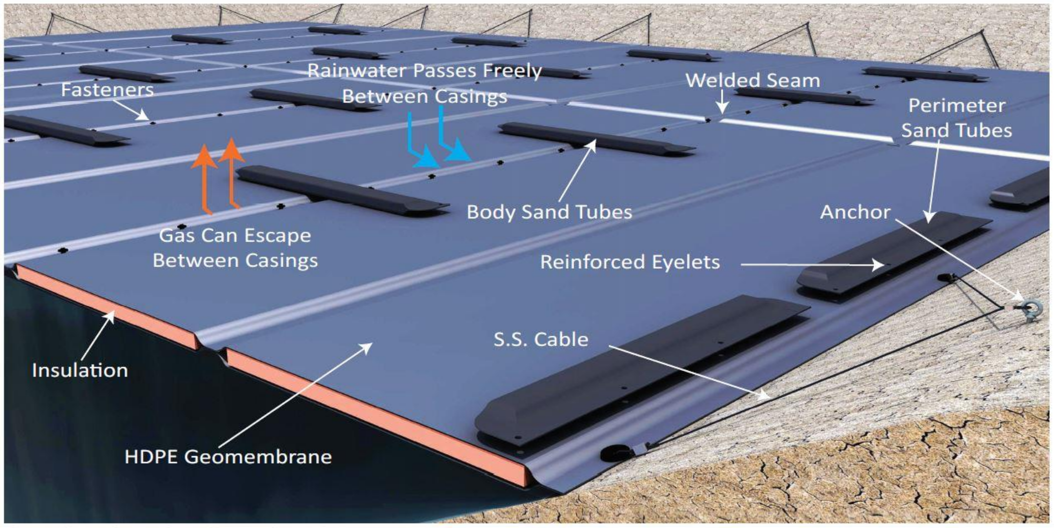


COMPONENTS OF THE LBTP



- Prevent short circuiting of water from influent to effluent and decrease area of dead zones
- Improve overall “mixing” of water within lagoons
- Can be used to segregate various treatment cells within a lagoon (i.e. – C/M, P/M, etc.)

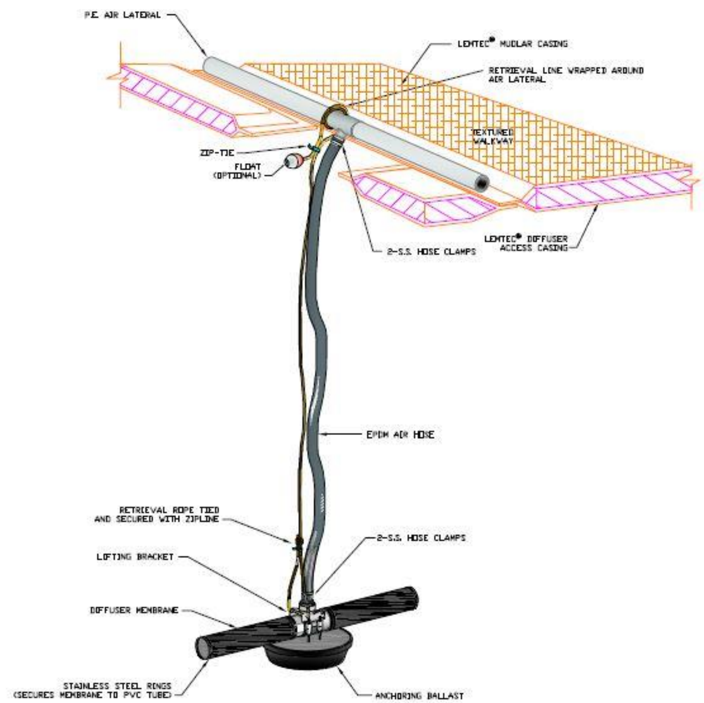
Baffle integrated into cover.



- Preserves temperature
- Eliminates algae
- Provides odor control
- Provides equipment access

- Aeration is required for:
  - Oxidation of organic matter (BOD)
  - Nitrification
  - Solids digestion

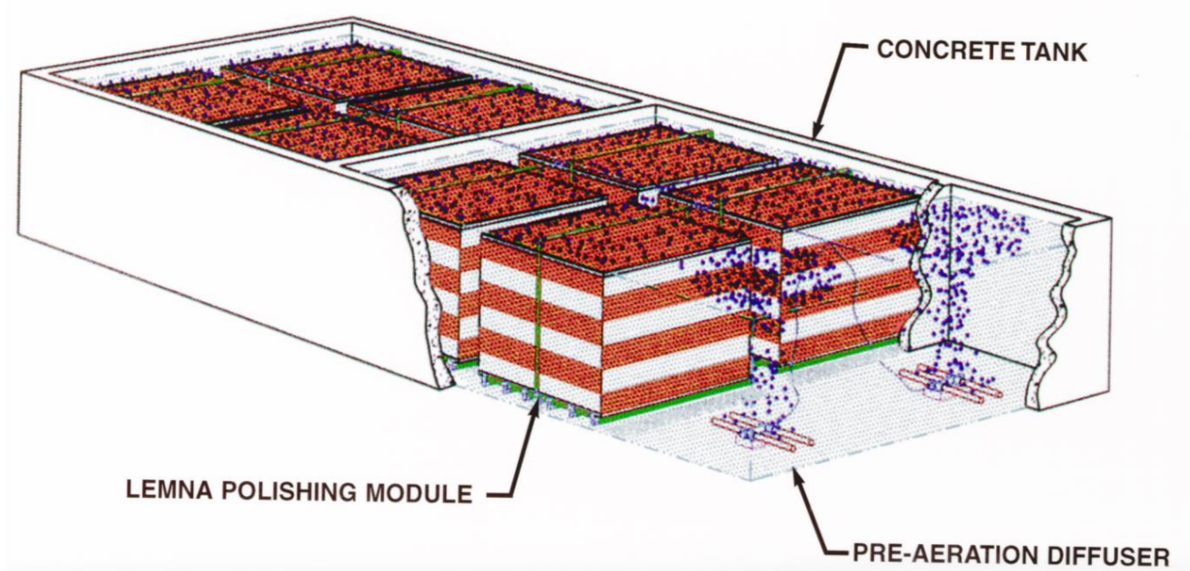
- Mixing is required to provide enough energy for suspension of solids:
  - Anywhere from 15 hp-30 hp/ 1 MG of volume is typical for complete mix


P.E. AIR LATERAL
LEMTEC® MUDLAR CASING
RETRIEVAL LINE WRAPPED AROUND
AIR LATERAL
TEXTURED
WALKWAY
ZIP-TIE
FLOAT
(OPTIONAL)
2-S.S. HOSE CLAMPS
LEMTEC® DIFFUSER
ACCESS CASING
EPDM AIR HOSE
RETRIEVAL ROPE TIED
AND SECURED WITH ZIPLINE
2-S.S. HOSE CLAMPS
LIFTING BRACKET
DIFFUSER MEMBRANE
STAINLESS STEEL RINGS
(SECURES MEMBRANE TO PVC TUBE)
ANCHORING BALLAST

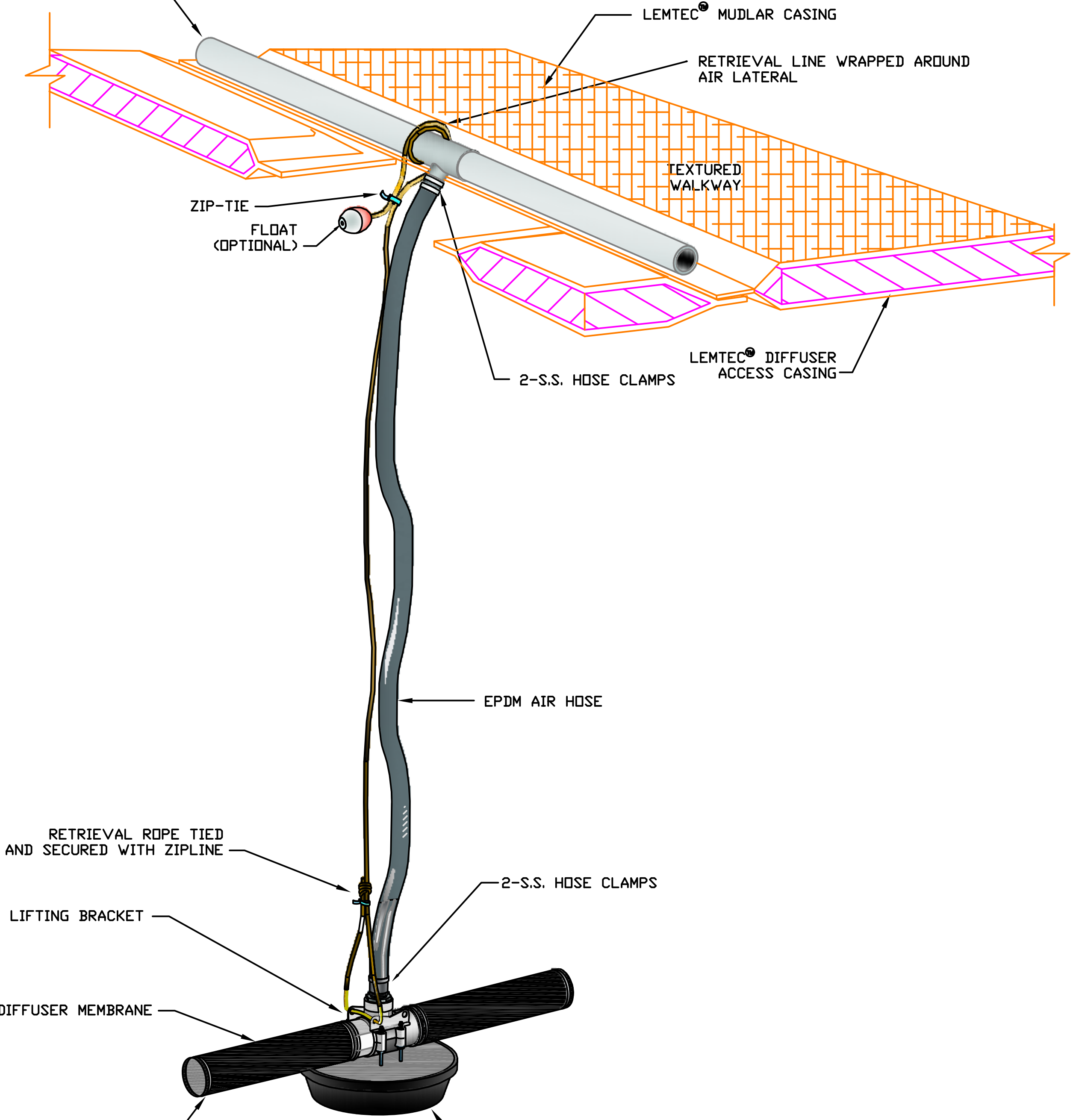
Attached Growth Reactors

Fixed film technology promotes stable concentrations of biomass.

- Increased solids retention times
- Polish BOD
- Reduce ammonia
- Establish a stabilized, more predictive environment



- Easily retrofitted to lagoons for increased performance
- Effectively removes ammonia and polishes BOD
- Submerged, attached growth process is reliable and consistent
- Out-of pond applications typically utilize concrete tanks



DRAWING STATUS	DATE

LEMTEC ™ BIOLOGICAL TREATMENT PROCESS

LOW RATE DIFFUSER

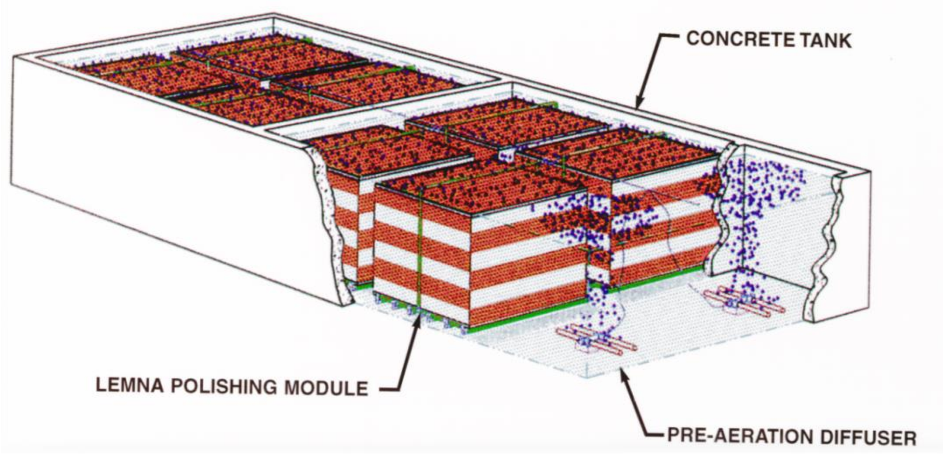
LEMNA ENVIRONMENTAL TECHNOLOGIES, INC.
4215 WHITE BEAR PARKWAY, SUITE 200 • VADNAIS HEIGHTS, MN 55110
PHONE: 612-253-2000 FAX: 612-253-2003 WWW.LEMNATECHNOLOGIES.COM

DRAWN: MS
DESIGNED: DAP
CHECKED: JAM / DEA
PROJECT NUMBER:
SCALE: NOT TO SCALE
DATE: NOVEMBER 2015

SHEET NUMBER:

Lemna Polishing Reactor

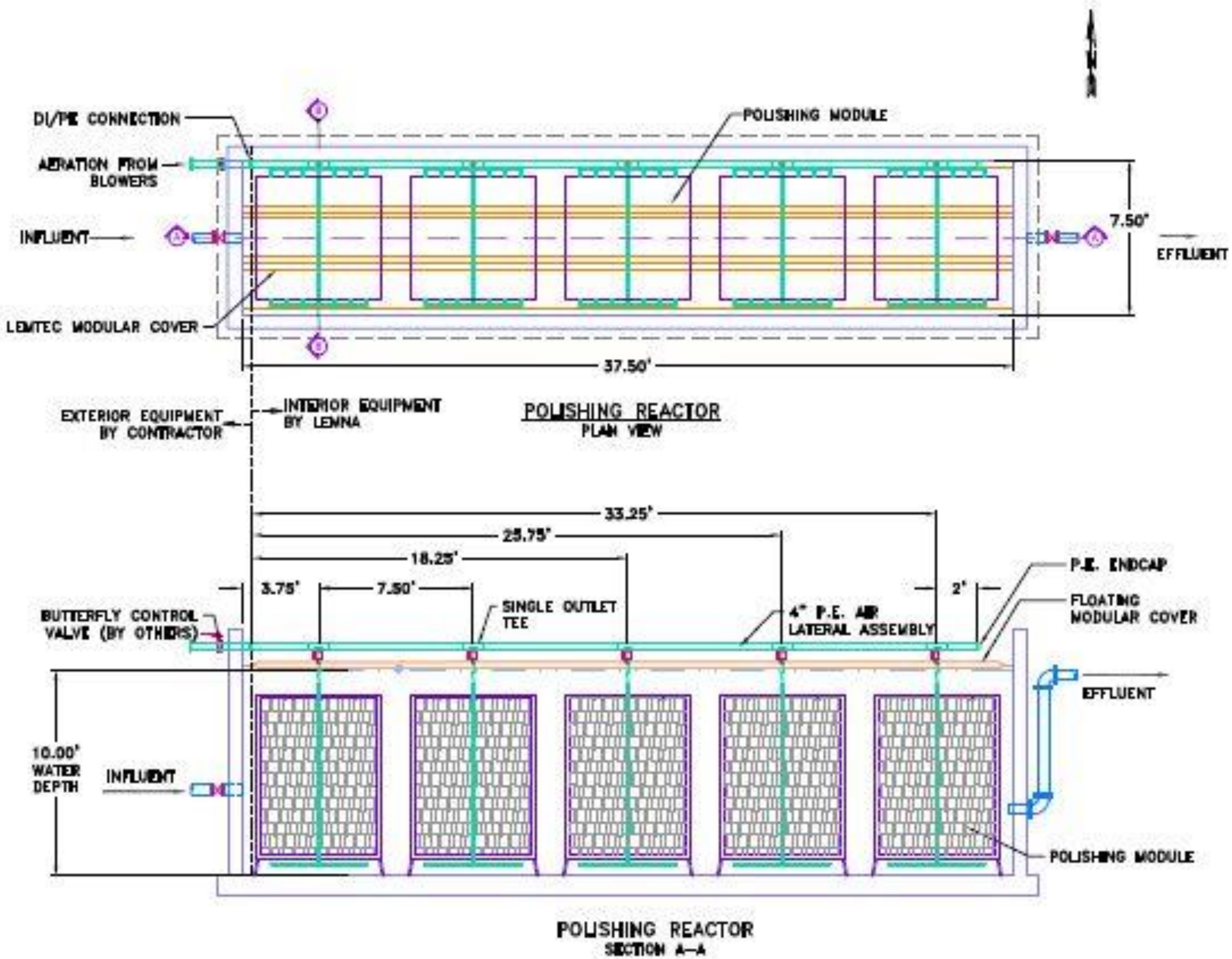
- Effectively removes ammonia and polishes BOD.
- Submerged, attached growth process is reliable and consistent.
- Applications typically utilize concrete tanks



- Simple operation, requiring virtually no operational interface.

- No internal moving parts and efficiently aerated fixed film attached growth media.

- Can be sized to handle flows from 20,000 gpd to 2,000,000 gpd.


DI/PE CONNECTION
AERATION FROM BLOWERS
INFLUENT
LEMTEC MODULAR COVER
POLISHING MODULE
7.50'
EFFLUENT
37.50'
EXTERIOR EQUIPMENT BY CONTRACTOR
INTERIOR EQUIPMENT BY LEMNA
POLISHING REACTOR
PLAN VIEW
33.25'
25.75'
18.25'
3.75'
7.50'
2'
P.E. ENDCAP
FLOATING MODULAR COVER
BUTTERFLY CONTROL VALVE (BY OTHERS)
SINGLE OUTLET TEE
4" P.E. AIR LATERAL ASSEMBLY
EFFLUENT
10.00' WATER DEPTH
INFLUENT
POLISHING MODULE
POLISHING REACTOR
SECTION A-A

TROJANUV3000™PTP | TROJANUV3000™B

WASTEWATER DISINFECTION

TROJANUV3000™PTP | TROJANUV3000™B

Simple, Dependable UV Solutions

Proven, chemical-free disinfection from the industry leader

UV is the most effective, safe and environmentally friendly way to disinfect wastewater. It provides broad-spectrum protection against a wide range of pathogens, including bacteria, viruses and chlorine-resistant protozoa (such as *Cryptosporidium* and *Giardia*).

The TrojanUV3000™PTP (Packaged Treatment Plant) and TrojanUV3000™B are two examples of simple, robust and operator-friendly UV systems used for the disinfection of wastewater. These highly flexible systems have demonstrated effective and reliable performance around the world. The TrojanUV3000 PTP is pre-engineered for quick, inexpensive installation with pipe runs using pre-fabricated, flanged stainless steel channels, or into existing chlorine contact basins and effluent channels. The TrojanUV3000 B offers increased capacity and is available with a controller that enables flow pacing to maximize operating efficiency and extend lamp life.

The system turns UV lamp banks on and off automatically to ensure the required dose is met using the fewest lamps and least electricity.

The proven infrastructure of the TrojanUV3000 PTP and TrojanUV3000 B have been continuously refined to enhance friendly operation.

TROJANUV3000™PTP | TROJANUV3000™B

Robust, operator-friendly solutions designed for economical disinfection

System Monitor/Control Center

TrojanUV3000 PTP – Optional

The optional System Monitor includes a submersible UV sensor, and provides digital output of UV intensity at each bank. Elapsed time display provides continuous readout of actual hours of operation (lamp hours). A dry contact enables a remote low UV intensity alarm.

TrojanUV3000 B

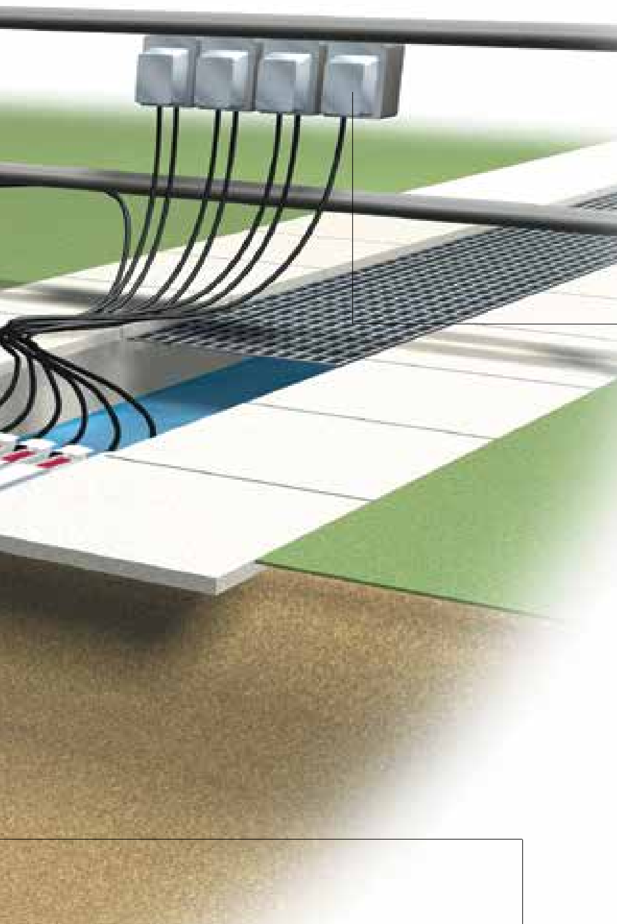
The System Control Center (SCC) provides control of all UV functions, tracks lamp hours, and uses a submersible UV sensor (one per bank) to monitor UV intensity. The SCC is capable of flow pacing – automatically turning banks of UV lamps off or on in response to changes in the flow rate in order to conserve power and prolong lamp life.

Water Level Control

TrojanUV3000 PTP

A fixed weir maintains the correct channel effluent depth over different flow rates, allowing a maximum head loss of 1.5 inches (3.8 cm). The system is also equipped with a drain for easy channel cleaning, and available for both concrete channels and stainless steel channel option.

Electronic Ballast



TrojanUV3000 PTP/B

The electronic ballast is mounted within its own Type 6P (IP67)-rated watertight enclosure within the module frame and is cooled by convection.

Power Distribution

TrojanUV3000 PTP

Each Power Distribution Receptacle (PDR) powers two (2) UV modules and allows for quick and safe electrical disconnect. The duplex ground fault interrupter receptacles ensure operator safety and are mounted inside Type 3R rain shield boxes.

TrojanUV3000 B

The Power Distribution Center (PDC) is constructed of stainless steel and is mounted across the channel. The PDC distributes power to individual modules and allows electrical isolation of each module for easy service.

TrojanUV3000 B

Available with a fixed weir or Automatic Level Control (ALC) gate in the channel to maintain the appropriate water level over the lamps. Engineers will work with you to select the appropriate level control device for your application.

UV Modules

TrojanUV3000 PTP/B

UV lamps are mounted on stainless steel frames. Lamps are enclosed in quartz sleeves and submerged horizontally and parallel to water flow. A bank is made up of multiple modules placed in parallel positions. All wiring, from ballasts to lamps, runs inside the module frame. A display showing individual lamp status is provided on top of each module.

Stainless Steel Effluent Channel

TrojanUV3000 PTP - Optional

An optional Type 304 stainless steel channel, complete with UV Module Support Rack, can be used. Channel can be installed as a freestanding structure connected to flanged pipes using the optional transition boxes.

Key Benefits

TrojanUV3000 PTP / TrojanUV3000 B

Increased operator, community and environmental safety. Uses environmentally friendly ultraviolet light – the safest alternative for wastewater disinfection. No disinfection by-products are created and no chlorine compounds are transported, stored or handled by plant staff.

Proven disinfection. Based on actual dose delivery testing (bioassay validation). Verified field performance data eliminates sizing assumptions resulting from theoretical dose calculations.

Reduced engineering and installation costs. The TrojanUV3000 PTP can be equipped with pre-fabricated stainless steel channels and transition boxes for in-line integration with existing flanged piping – thus minimizing engineering and installation costs. Both systems can be easily retrofitted into existing chlorine contact tanks and effluent channels, and come pre-tested, pre-assembled and pre-wired to minimize installation costs.

Designed for simplicity and reliability. Systems are straightforward to operate and require minimal operator involvement, thanks to modular design and robust components.

Operator-friendly maintenance. Our lamps are guaranteed for 12,000 hours of operation and can be replaced without tools in less than three minutes per lamp. Modules are electrically separate, allowing a single module to be removed without disrupting flow or taking the system off-line.

Outdoor installation flexibility. All components can be installed outdoors, eliminating the need and costs of a building, shelter and air conditioning for ballast cooling.

Well suited to changing regulations. Our systems do not have any negative impact on receiving waters, making them strategically sound choice for long-term treatment as regulations continue to become increasingly stringent.

Guaranteed performance and comprehensive warranty. Our systems include a Lifetime Disinfection Performance Guarantee.

Advanced, Self-Contained UV Modules

Compact footprint simplifies installation and eliminates air conditioning costs

Benefits:

- Space-saving, electronic ballasts are housed in the modules to minimize footprint size, installation time and costs
- Convection cooling of the ballasts eliminates costs associated with air conditioning or forced-air cooling
- Lamps are protected in a fully-submersible, Type 316 stainless steel frame
- All wiring and cables are safely enclosed inside the waterproof module frame – fully protecting them from effluent and UV light
- Modules are electrically separated from each other, allowing them to be individually removed for maintenance and spare modules quickly inserted to maintain maximum performance

The advanced, self-contained modules incorporate convection-cooled ballasts and feature a UV lamp status indicator (below) for at-a-glance confirmation that all lamps are operating.

- Streamlined modules minimize head loss and prevent build-up of debris on the lamps
- All module wiring is pre-installed and factory-tested

Innovative Ballasts and Enclosures Provide Significant Advantages	
Module-Mounted Ballasts	• Take up less space and reduce footprint, minimizing installation time and costs
Convection Cooling	• Housing the ballasts in the module allows for natural convection cooling to dissipate the heat of the ballasts into the air • The ballasts are kept sealed and protected • No air conditioning or forced-air cooling required
Clean, Water-Tight Protection	• Some suppliers use external cabinets with forced-air cooling. This introduces dust and moisture onto circuit boards and other electronic components, greatly reducing the life of these components • Internal housing in sealed modules keeps all components dry and clean
Internal Cabling	• All lamp/ballast wiring is contained within the module frame. This configuration protects wires and cables from exposure to effluent, debris fouling and UV light • Internal cabling allows all electrical connections within the module to be factory-tested

Proven Performance, Components and Design

Validated through regulatory-endorsed bioassay testing

Benefits:

- Performance data is generated from actual field testing (bioassay validation) over a range of flow rates, effluent qualities and UV transmittances
- Provides regulatory-endorsed physical verification that systems will perform as expected – ensuring public and environmental safety
- Most accurate assessment of system sizing needs
- Low-pressure lamps and ballasts have proven their outstanding reliability in thousands of installations
- Open-channel design allows cost-effective installation into existing effluent channels & chlorine contact basins
- Systems can be installed outdoors to reduce building capital costs
- Modular design is scalable for precise sizing, and expandable to meet new regulatory or capacity requirements

Gravity-fed, open channel design delivers cost savings at installation through simple retrofits into existing effluent channels and chlorine contact tanks. Rugged, proven components make operation and maintenance extremely cost-effective.

Designed & Built for Easy Maintenance

User-friendly design requires minimal service and operator involvement

Benefits:

- Lamps are warranted for 12,000 hours
- Routine maintenance can be scheduled and completed without disrupting disinfection
- Replacement of UV lamps can be completed without tools and requires less than three minutes per lamp

Lightweight, self-contained modules are operator-friendly and make routine maintenance quick and easy. Modules can be individually removed for periodic sleeve cleaning and lamp replacement after 12,000 hours. An optional, mobile cleaning rack simplifies maintenance procedures.

Highly Flexible Installation Configurations

Pre-engineered for cost-effective integration with piping or channels

Benefits:

- Designed to meet disinfection requirements with minimal engineering costs
- Can be installed in series to treat higher flows or provide additional redundancy
- Pre-engineered stainless steel channels with built-in weirs are installed as a freestanding structure
- Stainless steel channels are easily integrated with existing flanged piping using our highly flexible transition boxes (Figure 1)
- Optional turn boxes minimize system footprint by connecting stainless steel channels and allowing two banks in series to be installed side-by-side (Figure 2)
- Transition boxes allow flanged pipe connection on any of three sides for flexible integration (Figure 3)

Figure 1: Banks in Series – Side View

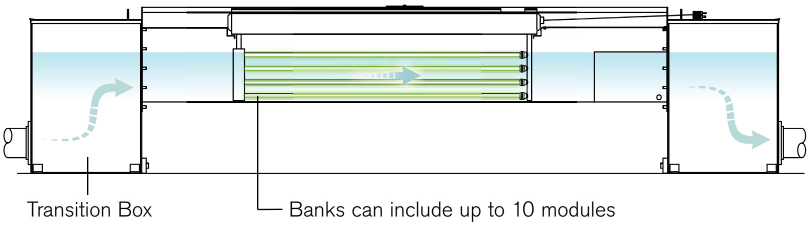


Figure 2: Banks in Series With Turn Box – Overhead View

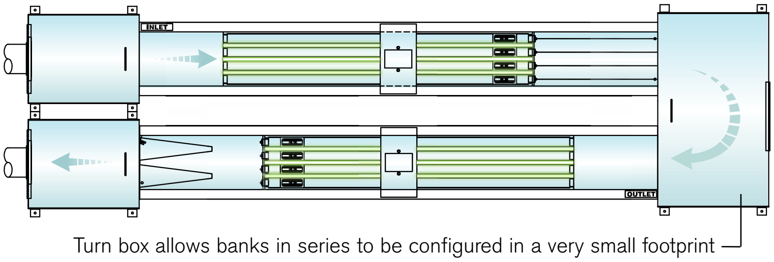
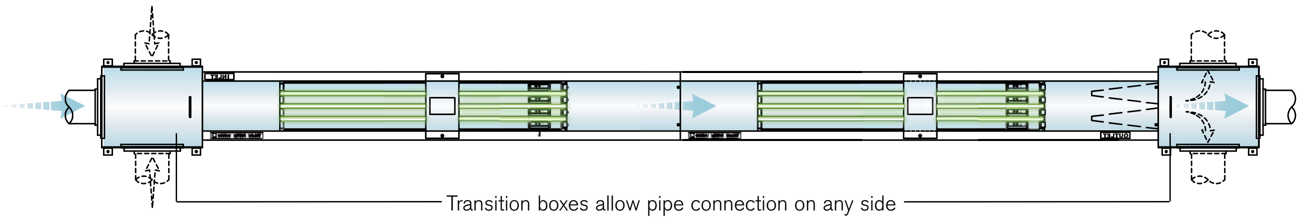


Figure 3: Banks in Series – Overhead View



Pre-engineered for simple, effective, low cost wastewater disinfection. The optional 304 stainless steel channels feature a UV module support rack, and can be installed as a freestanding unit. Turn boxes and transition boxes allow systems to be incorporated with maximum flexibility and minimal footprint.

Flow Pacing Reduces O&M Costs

TrojanUV3000 B system controller offers flow-pacing for increased operating efficiency

Benefits:

- The System Control Center (SCC) provides monitoring and control of all UV functions
- The SCC provides digital display of bank status, lamp hours, and UV intensity (mW/cm^2)
- The SCC allows the system to be flow paced – meaning the UV lamps of individual banks are turned on and off automatically in response to variations in flow rate (based on a flow meter signal)
- Flow pacing maximizes operating efficiency by matching UV output to disinfection requirements, and reducing electrical consumption during periods of low flow by turning lamps off (Figures 1 & 2)
- Flow pacing also increases the operating life of UV lamps, thereby reducing the frequency, expense and labor required for lamp replacement

The System Control Center monitors lamp hours and uses a submerged UV Sensor to feed accurate data on UV intensity for at-a-glance system status. The SCC also allows flow pacing to minimize operating and maintenance costs by turning banks on and off based on flow requirements

Flow Pacing Optimizes System Efficiency

Figure 1: Operation During Periods of High Flow

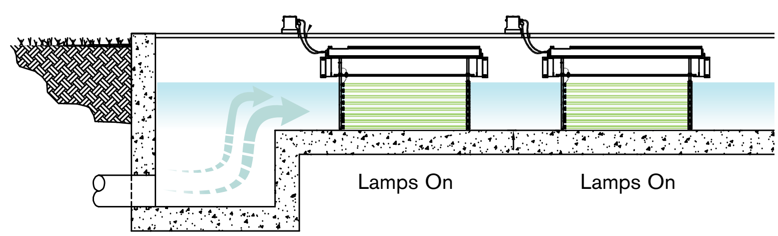
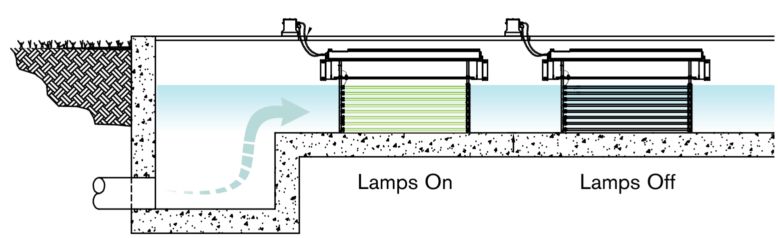


Figure 2: Operation During Periods of Low Flow



TROJANUV3000™PTP | TROJANUV3000™B

System Specifications

System Characteristics	TrojanUV3000 PTP	TrojanUV3000 B
Typical Applications	Up to 3 MGD (473 m^3/hr)	1 – 5 MGD (158 – 789 m^3/hr)
Lamp Type	Low-pressure	
Ballast Type	Electronic; non-variable	
Input Power Per Lamp	45 or 87.5 Watts	87.5 Watts
Lamp Configuration	Horizontal; parallel to flow	
Module Configuration	2 or 4 lamps per module	4, 6 or 8 lamps per module
Bank Configuration	Up to 10 modules per bank	Up to 20 modules per bank
Channel Configurations		
Lamp Banks in Series	Up to 2	Up to 3
Channel Options	Stainless Steel (TrojanUV option) or Concrete (by others)	Concrete (by others)
Flanged Transition Connections	Optional for stainless steel channels	–
U-Turn Connector Box	Optional for stainless steel channels	–
Level Control Device Options	Fixed weir	ALC gate or fixed weir
Enclosure Ratings		
System Monitor/Control Center	304 stainless steel	
Ballast Enclosure	Type 6P (IP67)	
Ballast Cooling Method	Convection; no air conditioning or forced air required	
Installation Location	Indoor or outdoor	
System Monitoring & Controls		
Controller	Optional; Monitoring only	Monitoring and bank control
UV Intensity Monitoring	Optional	Optional
Flow Pacing	–	Optional
Inputs Required	None	4-20 mA flow signal for Flow Pacing
Local Status Indication	Lamp Age (hours) UV Intensity (mW/cm^2) Bank Status (on/off) Low Intensity Alarm Lamp Failure Alarm	
Remote Alarms	UV Intensity (4-20 mA) Common Alarm (discrete)	
Location	Indoor or outdoor	
Maximum Distance from UV Channel	15 ft. (4.5 m)	20 ft. (6 m)
Electrical Requirements		
Power Distribution	Individual GFI Receptacles	Power Distribution Centre
Quantity Required	1 receptacle per 2 modules	1 PDC per bank
Power Input	120V; single phase	120V; single phase 208V; 3-phase 240V; single phase

TrojanUV is part of the Trojan Technologies group of businesses.

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www.trojanuv.com

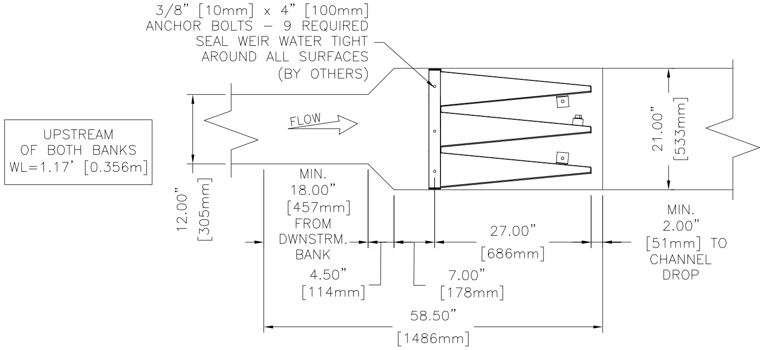
For a list of our global offices, please visit **trojanuv.com/contactus**.

TROJANUV™
A TROJAN TECHNOLOGIES BUSINESS

TROJAN UV3000™ PTP

EQUIPMENT INTERCONNECTIONS

No.	DESCRIPTION	FROM	TO
1	SPLITTER POWER SUPPLY 120V, 1 PHASE, 2 WIRE, ACTUAL DRAW 12.7 AMPS/SPLITTER PANEL	DISTRIBUTION PANEL (DP) (NOT SHOWN) (BY OTHERS)	SPLITTER PANEL (BY OTHERS)
2	SYSTEM MONITOR POWER SUPPLY 120V, 1 PHASE, 2 WIRE, 5 AMPS	(DP) (BY OTHERS) (NOT SHOWN)	SYSTEM MONITOR
3	POWER DISTRIBUTION RECEPTACLE (PDR) POWER SUPPLY 120V, 1 PHASE, 2 WIRE, ACTUAL DRAW 6.4 AMPS/PDR	SPLITTER PANEL (BY OTHERS)	PDR



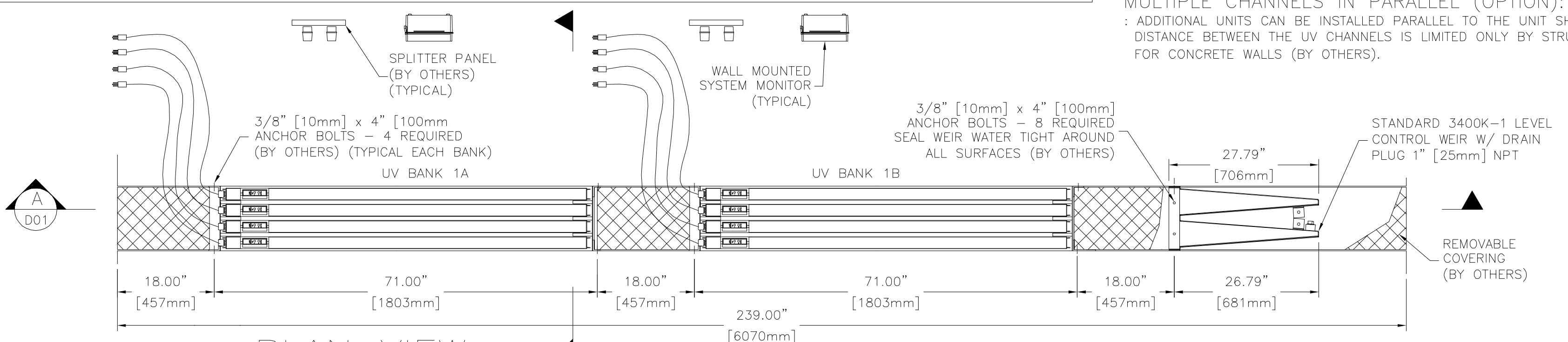
D3400K-1 WEIR (OPTION)

(REPLACES STANDARD WEIR SHOWN BELOW)

DOUBLE FLOW WEIR FRONT AND END VIEW NOT SHOWN - TOP OF WEIR ELEVATION WILL NOT CHANGE FROM STANDARD FRONT VIEW

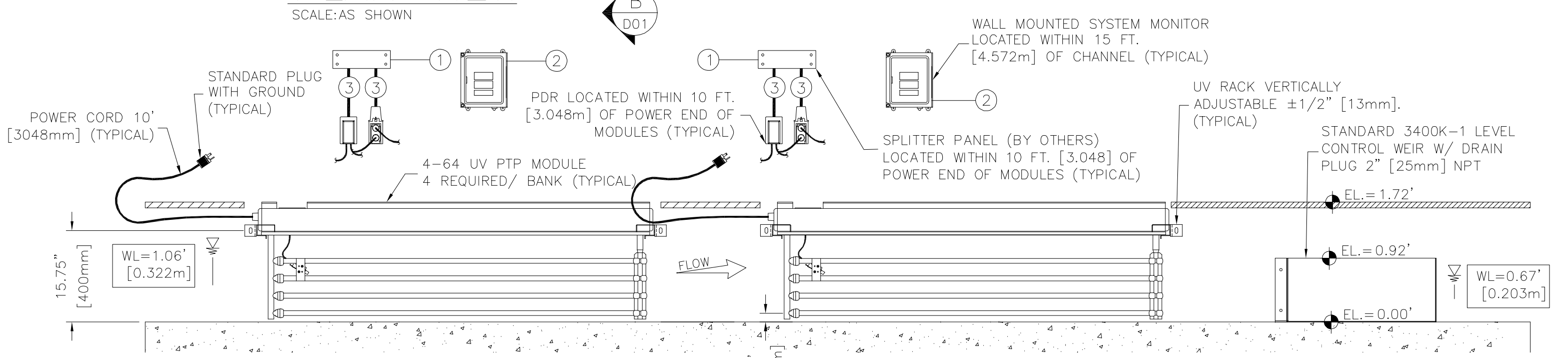
MULTIPLE CHANNELS IN PARALLEL (OPTION):

: ADDITIONAL UNITS CAN BE INSTALLED PARALLEL TO THE UNIT SHOWN. DISTANCE BETWEEN THE UV CHANNELS IS LIMITED ONLY BY STRUCTURAL REQUIREMENTS FOR CONCRETE WALLS (BY OTHERS).

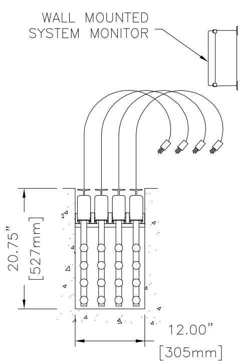


PLAN VIEW

SCALE:AS SHOWN



A SECTION
D01 SCALE:AS SHOWN



B SECTION
D01 SCALE:AS SHOWN

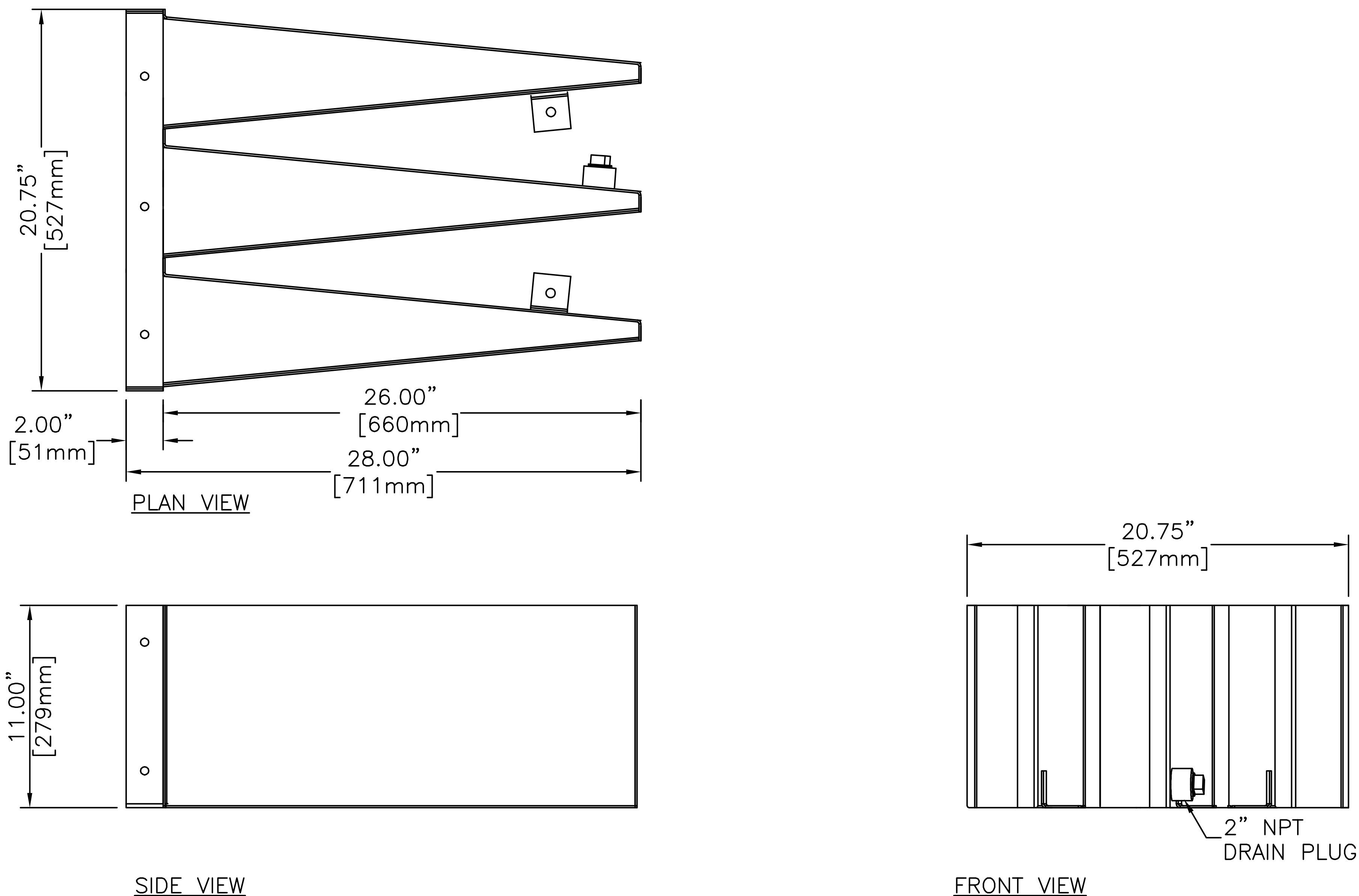
NOTES:

: DO NOT SLOPE CHANNEL FLOOR.
: CHANNEL WIDTH & DEPTH MUST BE KEPT WITHIN A TOLERANCE OF + OR -¼" [6mm].
: ANCHOR BOLTS ARE NOT SUPPLIED BY TROJAN TECHNOLOGIES INC.
: SYSTEM CONDUIT, WIRING, DISTRIBUTION PANELS & INTERCONNECTIONS BY OTHERS.
: ELECTRICAL REQUIREMENTS SHOWN ARE TO SUPPLY TROJAN UV EQUIPMENT ONLY. ELECTRICAL INRUSH FACTOR TO BE ADDED AS PER LOCAL CODE.
: ANY EXTRA OUTLETS NOT BEING USED BY TROJAN EQUIPMENT HAVE NOT BEEN INCLUDED IN THE INTERCONNECT AMPERAGE.
: CONTRACTOR TO REVIEW ALL TROJAN TECHNOLOGIES INC. INSTALLATION INSTRUCTIONS PRIOR TO EQUIPMENT INSTALLATION.
: ACCESS IS REQUIRED FOR MODULE REMOVAL - NOTE THE CHANNEL WIDTH AND ENSURE ADEQUATE ACCESS IS PROVIDED.

TROJAN UV

DESCRIPTION: LAYOUT, UV3000PTP-3400K-1 1 CHANNEL 2 BANKS 4 LAMP WEIR

DRAWN BY : QGP/CMS/SMC/LZ	DATE : 05SE13	DWG. NO. 3M0317	
CHECKED BY : LQ	DATE : 06MY17	PROJECT NO. N/A	
APPROVED BY : JLM	DATE : 06MY18	DWG NO. D01	REV. D
SCALE (11x17) : NOT TO SCALE	LOG NUMBER : N/A		



TROJANUV

DESCRIPTION: STD, UV3000PTP-UV D3400K-1 WEIR		STANDARD DRAWING NO. 3M0570
DRAWN BY : CAR/LZ/HM	DATE : 06MA09	REFERENCE NO. N/A
CHECKED BY : LQ	DATE : 06MY12	
APPROVED BY : JLM	DATE : 06MY12	DWG NO. D01 / REV. A
SCALE (8½x11) NOT TO SCALE	LOG NUMBER : N/A	

Final Report

PeroxyChem

VigorOx® WWT II
Disinfection Bench Scale Test for

Brandenburg, KY

March 28, 2017

Executive Summary

Bench scale testing successfully demonstrated that the VigorOx® WWT II peracetic acid (PAA) disinfection technology is effective for treating wastewater from the Brandenburg, KY wastewater plant to a target of a maximum *E. coli* concentration of 126 MPN / 100 mL. A secondary effluent sample was collected for testing. PAA dose rates of 1.5, 2 and 3 mg/L reduced the *E. coli* concentration to below the 126 MPN / 100 mL with a contact time of 10 minutes, and with 1.0 ppm PAA after 30 minutes.

- The *E. coli* concentration of the secondary effluent sample prior to disinfection was 5,335 MPN / 100 mL.
- It was reduced to 87 MPN / 100 mL at a dose of 1.5 mg PAA/L and contact time of 10 minutes, a reduction of 1.78 logs (98.4%). Further reduction was measured with increased contact time.
- A minimum Ct of 20 min-mg/L was sufficient to consistently achieve the disinfection goal of controlling *E. coli* to below 126 MPN / 100 mL.

Since the test is based on one sample, it is recommended that a field trial be conducted to validate the VigorOx® WWT II dose rates and contact times required to achieve the plant's disinfection goals under varying conditions. A PAA dose of 1.5 mg/L should be used as a starting basis for the field trial to insure that the *E. coli* limits are met.

This report and the conclusions herein are accurate based on the data generated from the bench test.

Philip Block

Philip Block, PhD
Technical Director – Water Treatment

I. Introduction

1.1 Test Objectives

A bench scale disinfection test was performed for a wastewater sample collected from the Brandenburg, KY wastewater treatment plant. The objectives of this test were to evaluate the disinfection efficiency of VigorOx® WWT II against *E. coli* for the wastewater samples and to determine the dose rate and contact time required to achieve compliance with the plant's National Pollutant Discharge Elimination System (NPDES) permit requirement.

The target for microbial reduction for this test was for *E. coli* not to exceed 126 MPN / 100 mL. Thislimit value was used as the criteria to determine the dose and contact time required for this study.

1.2 VigorOx® WWT II Peracetic Acid

VigorOx WWT II is a strong disinfectant that results from the equilibrium reaction between acetic acid (vinegar) and hydrogen peroxide (H_2O_2). The resulting solution contains 15% peracetic acid (PAA) and 23% hydrogen peroxide (see Figure 1 for the chemical structure). The PAA molecule attacks and kills microbial organisms of concern in wastewater treatment, such as fecal coliforms and *E. coli* by disruption of cell membranes.

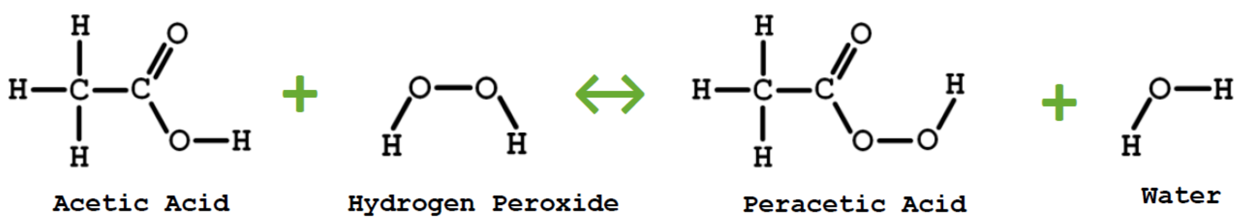


Figure 1 Chemical Structure of VigorOx WWT II

The oxidation potential of PAA is greater than that of hypochlorous acid and hypochlorite ion, resulting in typically lower dosages and contact times as compared to chlorine disinfection. In addition, PAA has a much lower aquatic toxicity profile than chlorine and decays rapidly in the environment. PAA is not a chlorine-based chemistry and does not result in the formation of chlorinated disinfection by-products. As a result, PAA generally does not need a quenching step, such as de-chlorination, reducing process complexity and cost.

2. Test Plan

A non-disinfected secondary effluent sample from the treatment plant was used in the test. The sample was collected from the plant and shipped to PeroxyChem's Research and Development Laboratory on March 13, 2017. The samples were received on March 14th and tested the day of arrival. Four VigorOx WWT II PAA doses and four contact times were used in the tests (shown in Table 2).

Table 2: Testing Doses and Contact Times

Wastewater Sample	VigorOx® WWT II Dose (mg/L as PAA)	Contact Time (minutes)
Brandenburg, KY	1.0, 1.5, 2.0, 3.0	10, 20, 30 and 45

During the jar test, the wastewater sample was measured into one-liter aliquots and placed into cleaned and disinfected beakers on a jar tester apparatus. The stirrers were set to 100 revolutions per minute for the duration of the test. VigorOx® WWT II PAA was dosed into the stirred beakers at the four different doses using a micropipette. Samples were taken at each detention time point for analysis of water quality parameters, in accordance to the test plan shown in Table 3. PAA concentration was determined by the CHEMetrics V-2000 method. *E. coli* concentrations were determined by the IDEXX method using Colisure media.

Table 3: Water Quality Testing Matrix(1)

Water Quality Parameters	Sampling Conditions	Methods/Instruments
E. coli (MPN/100 mL)	control(2) and four doses at four contact times	IDEXX
PAA Residual (mg/L)	four doses at four contact times	CHEMetrics I-2020 Single Analyte Meter
pH (standard unit)	control(2), and four doses at the 45-minute contact time	pH probe

Notes:

(1) All tests and measurements were conducted at PeroxyChem's Research and Development Laboratory in Tonawanda, NY
(2) Control: the non-disinfected secondary effluent sample.

3. Results and Discussions

3.1 Wastewater Characteristics

Selected physical-chemical and microbiological characteristics of the non-disinfected wastewater sample collected are shown in Table 4. The average *E. coli* concentration was 5,335 MPN / 100 mL. To achieve the disinfection goal of < 126 MPN / 100 mL, a minimum log inactivation of 1.63 (97.64 %) was required.

Table 4 Selected Characteristics of Non-disinfected Wastewater Sample

Water Quality Parameters	Concentrations
E. coli (MPN/10 mL)	5,335 (average of two measurements)
pH	7.48

3.2 Disinfection Performance

The disinfection testing results for *E. coli* are shown in Figure 2. The horizontal, red line represents the target disinfection goal of 126 MPN / 100 mL for *E. coli*.

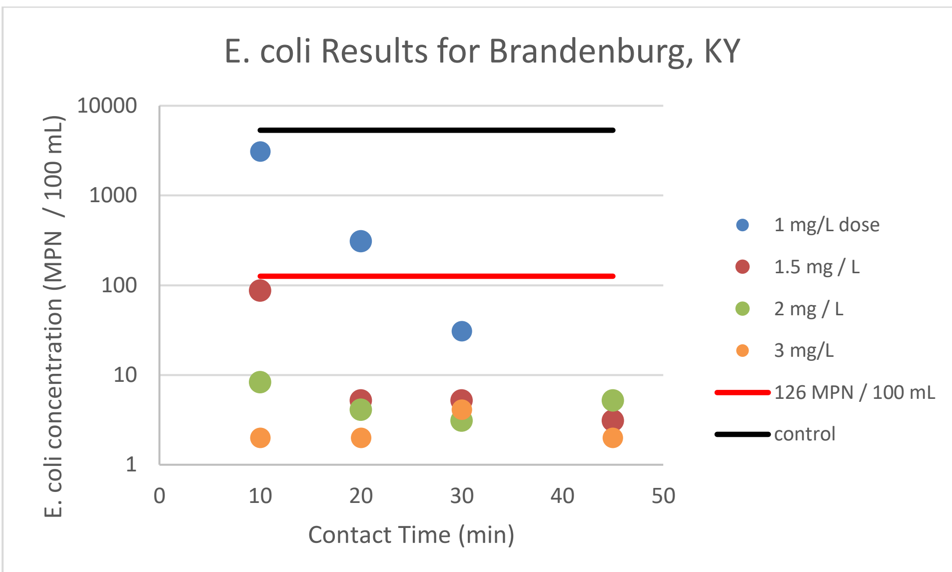


Figure 2 *E. coli* Concentrations as a function of PAA Initial Dose

The results indicated that VigorOx® WWT II was effective in disinfecting *E. coli* the wastewater sample at a PAA dose of 1.5, 2 and 3 mg / L and a contact time of 10 minutes, and at a dose of 1.0 mg PAA / L at a contact time of 30 minutes.

To assess the combined impact of dose and contact time on disinfection performance, Figure 3 illustrates *E. coli* concentrations at various Ct values (C being PAA dose and t being contact time). The results indicated that a Ct greater than 20 min-mg/L was required to reduce *E. coli* to achieve the disinfection goal.

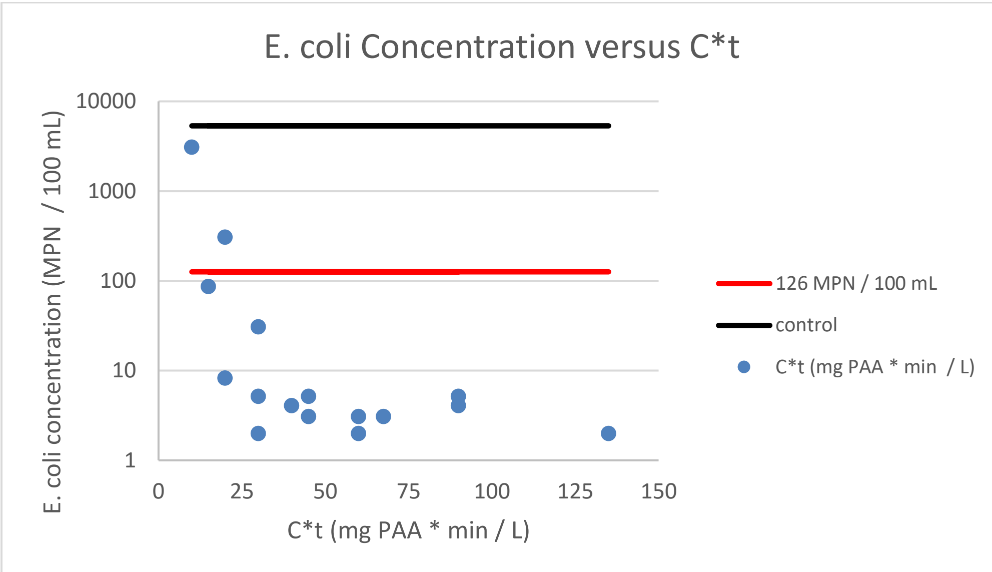


Figure 3 *E. coli* Concentrations at Various Ct

3.3 PAA Residual and Discharge Limits

The measured results of the PAA residual concentration as a function of contact time at various VigorOx® WWT II PAA doses are shown in Figure 4. The dashed lines drawn are the calculated results using a best fit equation based on first order decay kinetics as shown below:

$$C(t) = (C_0 - 0.67) \cdot e^{-0.0386*t}$$

where:

$C(t)$ = PAA concentration at time t (mg/L)
C_0 = PAA concentration at time 0 (mg/L) (PAA dose)
t = time (min)

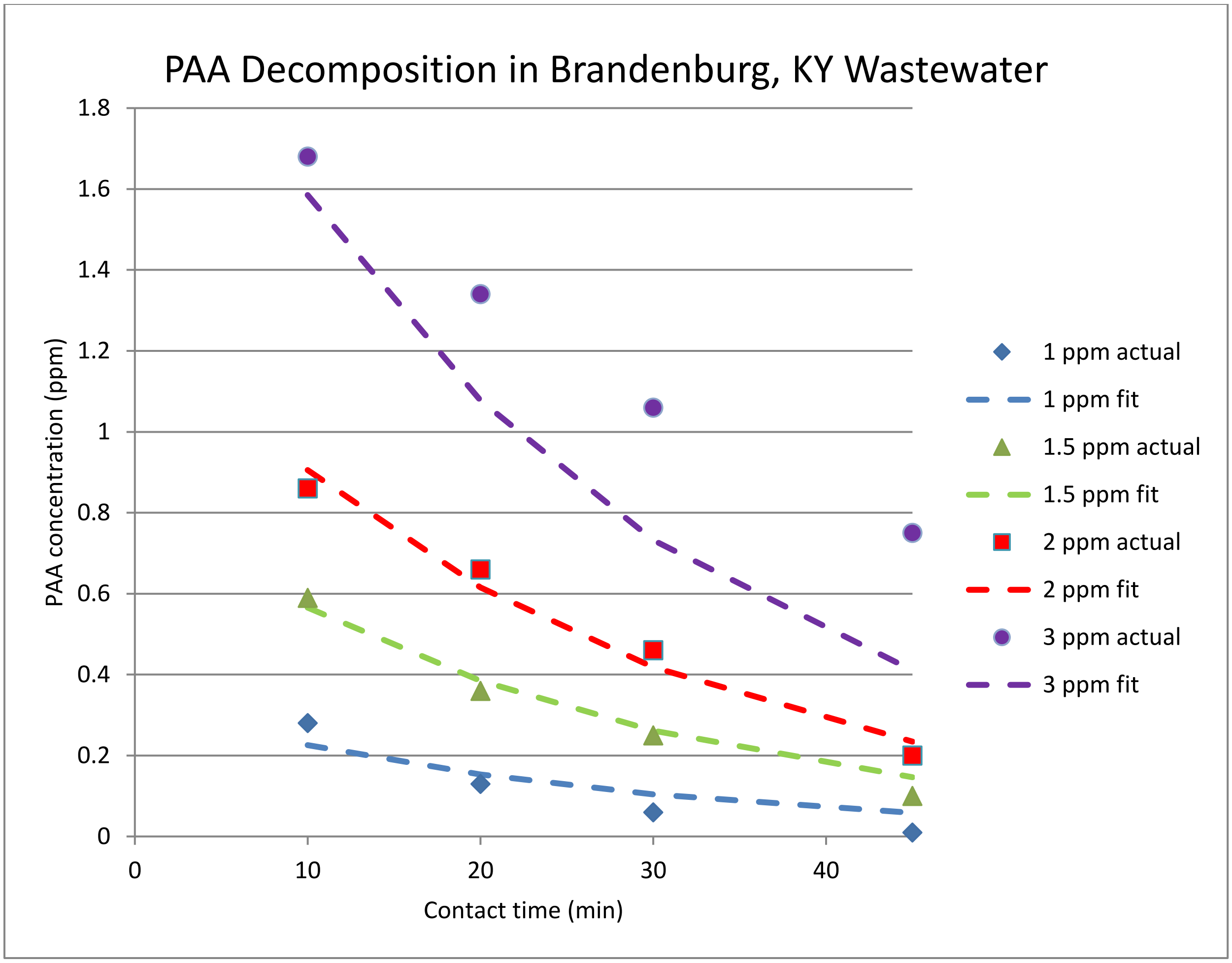


Figure 4 PAA Residual as Function of Contact Time at Various PAA Doses

The initial PAA demand in the waste water was calculated to be 0.67 mg / L. This is a bit higher than the average wastewater (around 0.3 mg / L), and may be a result of reduced metals or organics in the wastewater. The PAA residuals at all initial dose concentrations were below 1 ppm (0.8 ppm with an initial dose of 3 ppm at 45 minutes, and below 0.2 ppm at 45 minutes for 1, 1.5 and 2 ppm PAA dose).

Due to its low toxicity impacts to aquatic organisms, the USEPA approved labeling for VigorOx® WWT II has allowable, dilution factor based, discharge limits for PAA as:

1.0 ppm (mg/L), if dilution factor (DF) is < 12 or unknown

0.09 ppm x DF, if DF is equal to or greater than 12 (for example, if DF is 20, then the limit is 1.8 ppm)

Where $DF = \frac{plant\ effluent\ dishcarge + receiving\ stream\ 7Q10}{plant\ effluent\ discharge}$

(7Q10 is the lowest seven-day average stream flow of the receiving stream over a ten year period).

The site-specific limit for PAA residual at this plant needs to be confirmed with the State regulatory agency to determine whether quenching of PAA is necessary, if the plant implements the VigorOx® WWT II peracetic acid disinfection technology.

The pH decreased from 7.5 to 7.2 at a PAA concentration of 3 mg / L.

4. Conclusions

Bench scale testing successfully demonstrated that the VigorOx® WWT II peracetic acid (PAA) disinfection technology is effective for treating wastewater from the Brandenburg wastewater treatment plant to an *E. coli* concentration less than 126 MPN / 100 mL with a PAA dose rate of 1.5, 2 or 3 mg/L at a contact time of 10 minutes or at a rate of 1.0 mg/L at a 30-minute contact time.

The *E. coli* concentration of the secondary effluent sample prior to disinfection was 5,335 MPN / 100 mL. It was reduced to 87 MPN / 100 mL at a dose of 1.5 mg PAA/L and contact time of 10 minutes, a reduction of 1.78 logs (98.4%). Further data analysis indicated that a minimum Ct of 20 min-mg/L was sufficient to consistently achieve the disinfection goal of controlling *E. coli* to below 126 MPN / 100 mL.

The measured PAA residual was 0.8 mg/L at the effective dose of 3. mg PAA/L and a contact time of 45 minutes. For all other initial PAA dose concentrations, the residual was 0.2 mg / L or less after 45 minutes. The final site-specific discharge limit for PAA needs to be confirmed with the State regulatory agency to determine whether quenching of PAA before final discharge will be necessary if the VigorOx® WWT II PAA disinfection technology is implemented at this plant.

Since the test is based on one sample, it is recommended that a field trial be conducted to validate the VigorOx® WWT II dose rates and contact times required to achieve the plant's disinfection goals under varying conditions. A PAA dose of 1.5 mg/L should be used as a starting basis for the field trial in order to insure that the *E. coli* maximum limit may be met.